REPORT OF THE
SIXTH MEETING OF THE OZONE RESEARCH MANAGERS
OF THE PARTIES TO THE VIENNA CONVENTION FOR THE
PROTECTION OF THE OZONE LAYER

(Vienna, Austria, 19–21 September 2005)
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INTRODUCTION

The Sixth Meeting of the Ozone Research Managers of the Parties to the Vienna Convention for the Protection of the Ozone Layer took place at the Vienna International Centre in Vienna from Monday, 19 September, to Wednesday, 21 September 2005. The meeting was organized by the Ozone Secretariat of the United Nations Environment Programme (UNEP) in cooperation with the World Meteorological Organization (WMO), in accordance with decision I/6 of the Conference of the Parties to the Vienna Convention for the Protection of the Ozone Layer. A list of participants is provided in Annex A to the present report.

1. OPENING OF THE MEETING

Mr Marco González, Executive Secretary of the Ozone Secretariat, opened the meeting at 10.40 a.m. on Monday, 19 September 2005, on behalf of Mr Klaus Töpfer, Executive Director of UNEP. After welcoming participants, he thanked the Government of Austria for its arrangements to host and the World Meteorological Organization (WMO) for its cooperation in organizing various activities that were being held in conjunction with the third session of the Preparatory Committee for the Development of a Strategic Approach to International Chemicals Management (SAICM) to mark the twentieth anniversary of the adoption of the Vienna Convention for the protection of the ozone layer.

He recalled that the aim of the meeting of the Ozone Research Managers was to review existing national and international research and monitoring programmes in order to ensure their proper coordination and implementation, and to identify any gaps in such efforts. The meeting would be expected to produce a report with recommendations relating to future ozone research, ways to improve regional and global ozone monitoring and ways to expand cooperation between developed and developing countries. Those recommendations would be presented to the Conference of the Parties to the Vienna Convention at its seventh meeting, which would take place in conjunction with the Seventeenth Meeting of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer, to be held in Dakar, Senegal, from 12 to 16 December 2005.

He informed the participants that the first event to mark the twentieth anniversary of the Vienna Convention was a seminar on lessons learned from the Vienna Convention that were applicable to the chemicals agenda, to be held on the evening of Monday, 19 September 2005. The second was a Vienna Convention awards ceremony and reception, hosted by the Government of Austria, to be held on the evening of Wednesday, 21 September 2005. All participants at the sixth meeting of Ozone Research Managers were invited to attend.

Mr Paul Krajnik, Chair of the Executive Committee for the Implementation of the Montreal Protocol and representative of the Ministry of Environment, Youth and Family Affairs of Austria, welcomed participants to Vienna on behalf of the Austrian Government and recalled that, three days previously, on 16 September 2005, the United Nations and Governments around the world had celebrated the International Day for the Preservation of the Ozone Layer, which had provided an opportunity not only to reflect on the successful implementation of the Montreal Protocol and the Vienna Convention over the past two decades but also to look to the future. Referring to other multilateral environmental agreements, he emphasized the importance of adopting a holistic approach to environmental protection, as exemplified by holding the meeting of Ozone Research Managers at the same time as the SAICM meeting.
Mrs Elena Manaenkova, Director of the Atmospheric Research and Environment Programme (AREP) of WMO, described a joint initiative by the International Council for Science (ICSU) and WMO to sponsor International Polar Year 2007 - 2008 (IPY). Reviewing the objectives of the initiative, which included the enhancement of ozone observation networks, she pointed out that the initiative afforded a major opportunity to Ozone Research Managers, who might be able to take part in the activities of the observation stations and use the results of the research carried out under the initiative after the campaigns ended. In order to ensure the success of the initiative, WMO and ICSU had established a Joint Committee on IPY responsible for the scientific planning, coordination, guidance and oversight of activities at the international level. More than 40 national committees on IPY were established to coordinate activities at the national level. Drawing attention to the initiative’s website (www.ipy.org), she urged participants from all countries – and not only the polar ones – to contact their national committees and become involved in the initiative. Numerous project proposals had already been received by the IPY Joint Committee and efforts were being made to develop a well-resourced, comprehensive project to serve as a flagship project on ozone under the initiative.

2. ORGANIZATIONAL MATTERS

2.1 Election of the Chair

Mr Michael Kurylo (United States of America) was elected Chair of the meeting. Thanking participants for their vote of confidence, he recalled that the meeting had two very important purposes: first, it gave participants an opportunity to share experiences with regard to individual and international collaborative efforts relating to ozone and ultraviolet radiation; and second, and perhaps more important, it provided an opportunity for the Ozone Research Managers to produce a report and a set of practical recommendations, which would be presented to the Conference of the Parties to the Vienna Convention at its seventh meeting.

2.2 Adoption of the agenda

The agenda, which is reproduced in Annex B, was adopted.


Mr Kurylo reviewed the recommendations adopted at the fifth meeting of the Ozone Research Managers, on the themes of systematic observations, data archiving, research needs and capacity-building. He urged participants, when developing the new recommendations, to take into account the progress made and any setbacks in implementing those adopted at the fifth meeting.

Ms Megumi Seki, Scientific Officer of the Ozone Secretariat, reviewed the decisions of the sixth meeting of the Conference of the Parties to the Vienna Convention, in particular decision VI/2 on ozone-related monitoring and research activities, which had resulted from the recommendations of the fifth meeting of the Ozone Research Managers. A copy of the decisions was available to the participants. Recalling the provisions of decision VI/2, she informed the meeting that a trust fund for financing activities on research and systematic observations relevant to the Vienna Convention in developing countries and countries with economies in transition (CEITs) had been established in February 2003 pursuant to that decision, in cooperation with WMO. The terms of reference of that fund and a letter inviting Parties to contribute to the fund had been circulated to the Parties. On the issue of institutional arrangements, she said that a memorandum of understanding had been concluded between the Ozone Secretariat and WMO, covering the modalities of operation to allocate funds for projects issues such as maintenance and calibration projects for Global Environment Watch (GAW) ground-based stations and research and monitoring.
On the status of implementation of decision VI/2, she said that a total of $31,482 had been received to date, from Finland, Kazakhstan, Spain and the United Kingdom, and that one project, a Dobson inter-calibration workshop, had been held in Egypt in March 2004, for which purpose $15,000 had been disbursed. Another project was currently under preparation by WMO. She suggested that, at the seventh meeting of the Conference of the Parties to the Vienna Convention, Parties might be expected to consider extending the life of trust fund, which was originally intended to end December 2007, and that the Ozone Research Managers should perhaps indicate in their recommendations which specific activities required funding and the level of funding needed per activity.

4. CURRENT STATE OF THE OZONE LAYER

Mr Greg Bodeker of the National Institute of Water and Atmospheric Research of New Zealand, and a member of the Scientific Assessment Panel of the Montreal Protocol, gave a detailed presentation on the current state of the ozone layer. Noting that the state of the ozone layer varied according to latitude zone and altitude and underscoring the importance of seasonal dependence in trends, he said that the global average ozone level remained approximately 4 per cent depressed below a 1964 - 1980 baseline, up from a depression of approximately 5 per cent in the mid-1990s. He also drew attention to the value of multiple data sets. He explained that, although ozone remained severely depleted over the Antarctic, many indicators showed signs of the recovery of the Antarctic ozone hole; however, interpretation of recent changes in Antarctic ozone depended very much on the indicators used. Ozone variability over the Arctic was higher than over the Antarctic and showed greater dependence on inter-annual variability in stratospheric temperatures. Recently, as a result of a number of warm Arctic winters, two-year-running means of ozone levels showed that ozone over the Arctic had returned to values similar to those observed in the early 1980s. In the longer term (over the past four decades), however, the Arctic stratosphere had become far more susceptible to severe ozone depletion as a result of stratospheric cooling.

Noting that ozone levels remained depressed over the mid-latitudes of both hemispheres, he said that, over northern mid-latitudes, the magnitude of ozone anomalies had been reduced from around minus 6 per cent shortly after the Mount Pinatubo volcanic eruption to approximately minus 3 per cent over the past five years. Model calculations indicated that those increases in ozone may have been driven largely by changes in atmospheric dynamics. In terms of the mass of ozone removed from the atmosphere, the post-Pinatubo anomaly in northern mid-latitudes exceeded any of the Antarctic ozone holes. The lack of a response in ozone to the Pinatubo eruption over southern mid-latitudes remained unexplained. Ozone over southern mid-latitudes remained about 5 per cent depressed below the 1964–1980 baseline, with little change over the past two decades. Since 1979, there had been little change in ozone over the tropics, but column ozone did show a strong response to the solar cycle in that region. Summer-time ozone trends over southern mid-latitudes had been larger than over northern mid-latitudes.

In conclusion, he said that a number of studies had reported the onset of ozone recovery in different altitude and latitude regions of the globe. Identification of the onset of ozone recovery, however, required detailed attribution of the drivers of the observed changes. Incomplete understanding of the processes and magnitude of a solar cycle effect in ozone might confound correct attribution of recent positive deviations in ozone above the long-term trend to decreases in stratospheric halogen loading. Confirming that the Montreal Protocol had been effective in reducing stratospheric halogen loading, he said that, with continued compliance with the Protocol and its amendments and adjustments, full recovery of the ozone layer could be expected. Chemistry-climate models suggested that recovery to 1980 levels would occur over Antarctica in approximately 2065 and over the Arctic in approximately 2040. That level of recovery would occur in approximately 2050 in extra-polar latitudes.

In the ensuing discussion, participants raised a number of questions on ozone depletion and recovery. Regarding whether it was premature to claim ozone recovery, Mr Bodeker said that even in cases where a large volcano erupted and ozone levels declined, if the expectation, through modelling, was that ozone would have otherwise gone up, it would still be acceptable to claim recovery. On why overall ozone depletion in the Arctic had not been as marked as anticipated in 2005, despite low temperatures, he explained that it was the volume of the Arctic air mass at or
below 195K, which determined the extent of the ozone depletion, and not the absolute minimum temperature. In addition, a sudden warming in early March 2005 caused an early stop in ozone depletion processes.

5. GLOBAL ATMOSPHERE WATCH (GAW) PROGRAMME OF THE WORLD METEOROLOGICAL ORGANIZATION: GLOBAL OZONE AND UV-B RADIATION OBSERVING AND MONITORING SYSTEM

Mr Geir Braathen of WMO explained that the WMO Global Atmosphere Watch (GAW) monitoring programme had been established in 1989 by merging the Global Ozone Observing System and Background Air Pollution Monitoring Network of WMO. It was coordinated by the Environment Division of the Atmospheric Research and Environment Programme (AREP) of WMO. A central function of GAW was to serve as a global network for monitoring the chemical composition of the atmosphere. It was also involved in conducting scientific assessments that were needed for formulating and implementing environment protection policies and in the development of predictive capability modelling. It was motivated by a number of factors, including improved weather forecasting, ozone and reactive gas observations, climate change and climate prediction.

The monitoring component of GAW included professional activities to measure parameters indicative of climate change, which were conducted in GAW facilities across the globe. Such facilities included measurement stations, calibration facilities, training centres and data centres, equipped with reliable instrumentation and qualified personnel to keep the monitoring system operational and ensure its development. Surveying the work of those facilities, he drew attention to the Global Atmosphere Watch Station Information System (GAWSIS), which was being developed and maintained by the Quality Assurance/Scientific Activity Centre of Switzerland in collaboration with the GAW secretariat, the GAW World Data Centres and other GAW representatives to improve the management of information about the GAW network of ground-based stations. He also drew attention to the GAWSIS website (http://www.empa.ch/gaw/gawsis), which contained comprehensive information on all GAW stations.

In conclusion, he urged the meeting to make it clear in its recommendations that, although it supported large-scale activities, funds should be provided to support ozone research activities at the national level.

In the ensuing discussion, attention was drawn to the need for technical and financial support to be provided to developing countries. Mr Braathen urged participants to encourage the relevant authorities in their countries to contribute to the trust fund, which might be used to provide such support. In that connection, Mr Kurylo recalled that one of the recommendations of the fifth meeting of Ozone Research Managers was to provide funds to allow representatives of developing countries and countries with economies in transition to participate in activities relating to ozone research. Research institutions at all levels, in addition to Governments and international organizations, should be encouraged to sponsor the participation of such representatives.

6. NETWORK FOR THE DETECTION OF STRATOSPHERIC CHANGE (NDSC)

Mr Kurylo, speaking as Co-Chair of the Network for the Detection of Stratospheric Change (NDSC) Steering Committee, summarized the history and the goals of the Network and noted that NDSC consisted of a set of more than 70 high-quality, remote-sensing research stations for observing and understanding the physical and chemical state of the stratosphere and upper troposphere and for assessing the impact of stratosphere changes on the underlying troposphere and on global climate. As a major component of the international upper atmosphere research effort, NDSC enjoyed broad international participation and endorsement, but there was still a need for more NDSC research stations in the southern hemisphere and in the tropics.

Stressing that a commitment to data quality lay at the heart of NDSC, he outlined the measurement contributions made by NDSC to GAW and to the Integrated Global Atmospheric Chemistry Observation (IGACO) system and described future NDSC developments. He pointed out that, while NDSC remained committed to monitoring changes in the stratosphere with an
emphasis on the long-term evolution of the ozone layer, its priorities had broadened considerably to encompass issues such as the detection of trends in overall atmospheric composition and understanding their impacts on the stratosphere and troposphere, and establishing links between climate change and atmospheric composition. In conclusion, he said that further information on NDSC was available on the Network's web site (http://www.ndsc.ws), and also in various information publications.

In the ensuing discussion, Mr Kurylo explained, in response to a suggestion, that the best way for representatives of developing countries to become familiar with NDSC activities was to attend working group meetings, and encouraged them to contact the relevant working group representatives for additional information.

7. WORLD CLIMATE RESEARCH PROGRAMME PROJECT ON “STRATOSPHERIC PROCESSES AND THEIR ROLE IN CLIMATE” (SPARC)

Mr Kurylo, speaking as a member of the SPARC Scientific Steering Group, gave an overview of the aims, structure and present and future activities of SPARC. He noted that the World Climate Research Programme (WCRP) had established the Stratospheric Processes and their Role in Climate (SPARC) project in 1992 to consolidate knowledge on the role that the stratosphere played in Earth’s climate system. It was the initial goal of SPARC to stimulate research in areas connecting the stratosphere and climate, which had not received sufficient attention during the earlier international research focus on stratospheric ozone. To date, the success of SPARC had been largely attributable to its ability to respond to international scientific assessment needs, to focus on manageable projects where international coordination made a difference, and to produce clear deliverables, such as comprehensive scientific reviews. Of particular note had been the recognition that tropospheric variability could provide a forcing mechanism for the stratosphere and that stratospheric variations could significantly change the radiative forcing on the troposphere.

To improve understanding of the processes linking the stratosphere to climate, the SPARC Scientific Steering Group had identified several scientific themes around which international research could be encouraged. Those included stratospheric indicators of climate change; stratospheric processes and their relationship to climate; and modelling of stratospheric effects on climate. Through a series of initiatives such as the establishment of working groups, the organization of workshops, and the authorship of review or assessment reports, SPARC had fostered a number of significant accomplishments under each of those themes. He described some of the current SPARC projects that were directly linked to WMO/UNEP ozone assessment and said that details of the SPARC organization, its implementation plan, and its initiatives could be found on its website at http://www.atmosp.physics.utoronto.ca/SPARC/index.html

8. SCIENCE, ENVIRONMENTAL EFFECTS AND TECHNOLOGY AND ECONOMIC ASSESSMENTS UNDER THE MONTREAL PROTOCOL

8.1 Status And Plans for the 2006 Assessment

Mr Ayite-Lo Nohende Ajavon, Co-Chair of the Montreal Protocol Scientific Assessment Panel (SAP), introduced the 2006 scientific assessment report that was currently being prepared by the Panel under the auspices of WMO and UNEP, in response to the Montreal Protocol. The report would be used by Governments and representatives of industry as key scientific input to decisions relevant to the protection of the ozone layer. He outlined the key features of the report, which included an executive summary, detailed chapters and a section containing frequently asked questions about ozone. He said that Parties to the Vienna Convention and its Montreal Protocol had identified topics addressed in previous reports and which needed to be reviewed, and had nominated scientists as potential contributors. Furthermore, the scientific community had provided comments on research advances and on the structure of the assessment report. He outlined the stages in the development of the report and explained that the final report would be available in spring 2007.
8.2 Special Report by The Intergovernmental Panel on Climate Change and the Technology and Economic Assessment Panel on Safeguarding the Ozone Layer and the Global Climate System

Mr Stephen O. Andersen, Co-Chair of the Montreal Protocol Technology and Economic Assessment Panel (TEAP), introduced the special report by the Intergovernmental Panel on Climate Change (IPCC) and TEAP on safeguarding the ozone layer and the global climate system, which focused on issues related to hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs). A summary of the report was available in the meeting room. In his introduction, he noted that the world owed a debt of gratitude to scientists for sounding the alarm, guiding policy and monitoring recovery with regard to ozone depletion. He said that the special report, which had been prepared by a steering committee co-chaired by TEAP and IPCC, was a good example of cooperation between the assessment panels of different international treaties and the results achieved illustrated the advantages of such interaction and cooperation.

Summarizing the contents of the report, he said that ozone-depleting substances produced before the Montreal Protocol phase out were not controlled by either the Montreal Protocol or the Kyoto Protocol to the United Nations Framework Convention on Climate Change. Uncontrolled emissions from stockpiles, products such as refrigeration and air conditioning equipment and insulating foam accounted for approximately 2.5 gigatons of carbon dioxide equivalent per year, which was about 10 per cent of all carbon-equivalent greenhouse gas emissions between 2000 and 2010. The activities under the “mitigation scenario” of technically feasible options and coordinated investment described in the IPCC/TEAP special report provided an opportunity to protect the ozone layer further and to reduce greenhouse gas emissions significantly. Financial credit for ozone-depleting substance greenhouse gas reductions could finance accelerated phase out and reduced bank emissions of those substances. He suggested that scientists might wish to calculate the reduction in stratospheric chlorine loading and the ozone layer recovery that would result from the actions under the mitigation scenario.

In conclusion, he said that it was clear that the work of ozone research managers was vital to the implementation of the Kyoto and Montreal protocols. He acknowledged the frustration felt by scientists because of the lack of funding for scientific research and said that greater efforts were clearly needed to support such research.

9. NATIONAL REPORTS ON EXISTING AND PLANNED ACTIVITIES RELATING TO OZONE RESEARCH AND THE MONITORING, CALIBRATION AND ARCHIVING OF MEASUREMENTS; AND ON UV-B MONITORING AND INITIATIVES AIMED AT THE PREVENTION OF UV-B AND SUN-RELATED INJURIES

The meeting had before it 48 national reports submitted by Parties to the Vienna Convention on their existing and planned activities relating to ozone research and on the monitoring, calibration and archiving of measurements. The reports also included information about UV-B monitoring and initiatives aimed at the prevention of UV-B and sun-related injuries. The reports are reproduced in Annex C to the present report, in alphabetical order by country. Representatives of 39 Parties presented oral summaries of their national reports to the meeting. An opportunity was provided for participants to pose questions and comment on key issues raised by the national reports, as input to the recommendations developed under agenda item 11. Following the discussion, Mr Kurylo said that issues arising from the national reports would be reflected in the recommendations.

Participants were invited to discuss those recommendations, and raise points on their success or failure to implement the recommendations of the fifth meeting of the Ozone Research Managers.

A description of events organized to mark the twentieth anniversary of the adoption of the Vienna Convention was provided by Mr González, Executive Secretary of the Ozone Secretariat, in his opening statement (see chapter 1 of the present report).

11. ADOPTION OF THE RECOMMENDATIONS AND THE REPORT

On the morning of Wednesday, 21 September, the meeting adopted the draft report of the meeting, on the basis of the draft text circulated in the meeting room and on the understanding that the Ozone and WMO secretariats would be entrusted with its finalization.

On the afternoon of Wednesday, 21 September, the meeting adopted the recommendations reproduced below, to be forwarded to the Conference of the Parties to the Vienna Convention at its seventh meeting. The recommendations were developed following discussions on the basis of the national reports and presentations made at the meeting. The recommendations are structured as set out in the following sections.

11.1 Introduction

11.1.0 The basis for the recommendations presented in this report is derived from information contained in the national reports presented at the 6th Meeting of Ozone Research Managers, progress and strategy reports from various international programmes and projects, and reports from recent and ongoing assessment activities. It is not the purpose of these recommendations to reproduce this information, but, rather, to draw from it. In particular, shortcomings in existing observation systems are documented in the national reports.

11.1.1 Although considerable progress has been made over the last decade in understanding the role of halogen chemistry in stratospheric ozone loss, there are a number of uncertainties whose resolution define the need for present and future observations and research. The effectiveness of the provisions of the Montreal Protocol and its Amendments has been clearly observed in the declining atmospheric abundances of many ozone-destroying species. In fact, the abundance of effective equivalent stratospheric chlorine (EESC) has been declining slowly for more than five years. Nevertheless, the abundances of many of the replacements for ozone-depleting substances (ODSs) still are increasing, and EESC will remain above pre-1980 levels for several decades. Hence, stratospheric ozone will remain vulnerable to chemical depletion for much of the current century. This vulnerability is highly dependent on climate-induced atmospheric changes. Further, the vulnerability would increase as a result of enhanced atmospheric aerosol loading resulting from major volcanic eruptions. This ozone vulnerability is coupled to continuing risks associated with the effects of increased UV radiation on human health and ecosystems.

11.1.2 Observations and analyses indicate that the rate of stratospheric ozone depletion at midlatitudes has slowed in recent years; however, over the polar regions, while some indicators show reductions in ozone depletion, these have not been unambiguously attributed to changes in stratospheric halogen loading (i.e., declining EESC). At midlatitudes and in the polar regions, other changes in atmospheric composition and dynamics also may be responsible. Continued research and observations are critical to quantifying the chemical and dynamical components of these changes in ozone and, thus, to labeling such changes as ozone recovery associated with anthropogenic halocarbons. Ozone recovery will occur in an atmosphere that is markedly different from pre-1980 conditions. Climate change associated with increased abundances of greenhouse gases is expected to alter the nature and timing of ozone recovery. Specifically, cooler
stratospheric temperatures resulting from climate change will enhance ozone-loss processes, thereby increasing ozone vulnerability in the polar regions, particularly in the Arctic. Observations have shown that cold Arctic winters have been characterized by lower minimum temperatures in the stratosphere. Further, some greenhouse gases pose additional direct threats to ozone through other chemical-depletion cycles. Ozone is a greenhouse gas, and quantifying its role in climate change requires continued high-quality measurements of both total abundance and vertical profile. The strong coupling between climate change, ozone production and loss, and accompanying changes in UV radiation at the ground places more stringent demands on long-term research and measurement needs, many of which are documented in The Integrated Global Atmospheric Chemistry Observations (IGACO) theme report [September 2004] prepared by WMO and ESA under the auspices of the Integrated Global Observing Strategy (IGOS).

11.1.3 As stated in paragraph 11.1.1, ozone vulnerability raises concerns about the adverse effects of increased UV radiation on human health and ecosystems. While a number of regional UV observational networks have been put in place in recent years, there remains a need for a stable, long-term observational capability that is geographically balanced. Without such a capability, the necessary high-quality UV data record cannot be obtained. Various atmospheric effects of climate change (e.g., cloud cover, aerosol abundance, albedo, temperature) on ground-level UV may actually be larger than ozone-induced effects. This recognition places increased demands on improving the observational capabilities for tracking such UV changes, and thereby providing necessary data for effects research. Further, biological effects due to increasing UV may be affected by increased temperature associated with climate change.

11.1.4 The considerable advances achieved in scientific understanding have been used by some to suggest a lessening need for long-term observational systems. On the contrary, the complexities of ozone and UV science highlighted above require the continuation and expansion of systematic measurement and analysis capabilities for tracking the evolution of ozone- and climate-related source gases and parameters, for detecting and tracking the stabilization and expected recovery of stratospheric ozone, for attributing changes in radiation forcing to changes in the ozone profile, and for deriving a global record of ground-level UV radiation.

11.1.5 The Sixth Meeting of the Ozone Research Managers, in recognition of the above issues, adopted the following recommendations. In doing so, they noted that international funding and cooperation are essential for their implementation, and noted once again that past recommendations have not received sufficient attention due to the absence of such funding and cooperation. This has exacerbated problems associated with the maintenance of existing instruments and networks, and with the development and implementation of new capabilities. Further, the implementation of the recommendations requires research and observational capabilities throughout developed and developing countries. Several international global-change initiatives have been formulated recently. Their success requires scientific capabilities at all national levels. Hence, intensified capacity building in developing countries and countries with economies in transition (CEITs) is required. Such capacity building is in the interests of all Parties, since the creation of a scientific community in developing countries will not only contribute to global ozone and UV science, but it will serve as the basis to provide local policymakers with scientific arguments on long-term implementation of the Montreal Protocol and its Amendments. Further, such expertise will enable the participation of experts from developing countries in the international assessment process.

11.2 Systematic Observations

Evaluation of the state of the ozone layer and an understanding of ground-level UV radiation require a stable, integrated global observing system consisting of ground-based, airborne, and satellite measurements. While synoptic-scale measurements are mainly
derived from satellite data, ground-based and airborne measurements add increased
temporal and spatial resolution, and provide critical validation of satellite sensors.
Continuing validation of all observational components is necessary to insure the high quality
of the data products. The continuity and long-term stability of these highly complementary
measurements are necessary to assess the onset of ozone layer recovery, to monitor its
evolution, and to track changes in ground-level UV radiation associated with ozone and
climate.

- Provide financial and institutional support to maintain and to expand well-calibrated ground-
based measurement networks for column ozone, including both spectral and filter
instruments. This includes the maintenance and preservation of aging instruments, the
deployment of unused instruments to developing countries and CEITs, the application of
new technologies, and the development and maintenance of adequate regional calibration
facilities including, but not limited to, the M-124 instrument network.

- Provide financial support to continue existing long-term profiling of ozone, and to enhance
these measurements in data-sparse areas, particularly in the tropics.

- Provide resources to continue and extend the long-term global column ozone trends record
provided by validated and quality-controlled space instruments. This requires the continued
development of a homogeneous data record from multiple instruments.

- Provide financial support to maintain both ground-based and space-borne measurement
capabilities for climate- and ozone-related trace gases and atmospheric parameters. This
includes ground-based networks, such as NDSC and WMO GAW, and existing space
instruments.

- Continue the implementation of ozonesonde standard operating procedures, and extend
these procedures to other ozone and UV instrument types.

- Maintain the radiosonde network, and expand it into areas with inadequate coverage,
especially the tropics. Network funding should accommodate the reporting of higher-
resolution radiosonde data to the World Data Centres, and the recovery, reprocessing, and
archiving of historical radiosonde records.

- Maintain and expand UV networks, including both spectrally resolved and broadband
instruments, to achieve geographical balance and to maintain long-term stability. This
requires financial support for the establishment and/or expansion of calibration facilities on
regional and global scales.

- Provide financial support to conduct regularly scheduled intercomparisons of instruments,
algorithms, and standards associated with measurements of ozone, ozone- and climate-
related trace gases, and UV radiation in order to maintain long-term data quality and
integrity.

- Continue operations of unique high-latitude measurements and facilities, both in the Arctic
and the Antarctic. This includes the reactivation of measurement sites recently closed due
to funding reductions.

11.3 Research Needs

There are a number of new unanswered questions with respect to expected ozone recovery
and the interrelationship between ozone and climate change. The ability to predict future
ozone behavior requires quantification of the roles of chemical and dynamical processes
responsible for ozone production, loss, and distribution, and their uncertainties. The
development of realistic scenarios of the future abundances of anthropogenic and biogenic
trace gases also is required. The parameterization of these processes in chemical
transport models remains challenging. In addition, these processes are occurring in a
continually changing atmosphere. Further research is needed on the response of ground-
level UV to changes in ozone, as well as to climate-driven changes in other atmospheric
parameters. Research is required not only to study biological vulnerability to increased levels of UV radiation but also other stress factors (i.e., integrated stress assessments).

- Support studies to quantify the chemical and dynamical components of polar and mid-latitude ozone loss in order to understand ozone evolution in a changing atmosphere. These include:
  - Studies examining the effects of climate change on ozone production, loss, and distribution, as well as possible feedbacks.
  - Studies investigating the dynamical coupling between the upper troposphere and lower stratosphere, particularly as it applies to water vapour, short-lived halogen species, and ozone.
  - Studies of aerosol and polar stratospheric cloud microphysics, and of cirrus in the tropical transition layer.
- Support studies aimed at understanding the budgets of ozone- and climate-related trace gases. This includes studies of the effects of climate change on the sources, sinks, and lifetimes of these gases.
- Support studies on the atmospheric effects of climate change (e.g., cloud cover, aerosol abundance, albedo, temperature) on ground-level UV radiation.
- Support studies on the consequences of interactions between ozone and climate on human health and ecosystems, including longer exposure to increased UV radiation due to a delayed recovery in the stratospheric ozone layer, the effects of increased temperature on the incidence of UV-induced skin cancer, and other biological impacts.

11.4 Data Archiving

The archiving and accessibility of ozone and UV data are as important as the measurements themselves. WMO's World Ozone and Ultraviolet Data Centre (WOUDC), operated by the Meteorological Service of Canada in Toronto, is the primary repository of the world's ozone data. However, additional ozone and UV measurement data are held at individual stations and often are archived at other data centre facilities. It must be recognized that data archiving is a resource-intensive activity; hence, it is important that funding provided for research and observations be adequate to include data archiving activities. Further, it is important that efforts be undertaken to transfer all ozone and UV data to the WOUDC, as well as to conduct re-evaluations of historical data.

- Encourage the submission of near-real-time data for column ozone, ozone profiles, ancillary ozone- and climate-related data, UV radiation, and campaign data to the appropriate local and world data centres. Funding for such data archiving activities should be included in the resources provided for research and observations.
- Urge all data centres to develop procedures for the prompt submission of their ozone, UV, and ancillary ozone- and climate-related data to the World Ozone and Ultraviolet Data Centre (WOUDC). Data archiving must include detailed metadata that describe the quality of the measurement and the instrument history.
- Provide funding for archiving raw data from various observational networks, either at the local institution or at the WOUDC, as appropriate. It is understood that archiving raw data does not replace the archiving of final data products.
- Provide continued support for the re-evaluation of the historical ozone, UV, and trace-gas data, in order to preserve and improve the long-term records.
11.5 Capacity Building

Many of the world’s ozone- and UV-measuring stations are located in developing countries and CEITs. The instruments used require sophisticated calibration and maintenance, much of which is unavailable without international capability. At present, there is an insufficient number of regional centres for research, calibration, and validation in developed and, especially, in developing countries. Therefore, it is vitally important that sufficient resources are made available to maintain the current global network of observations, and to expand it to uncovered areas.

- Support and encourage regional and bilateral cooperation and collaboration among developed and developing countries and CEITs to provide a global expertise in ozone and UV measurements and research.
- Provide resources for scientific and technical training, at and beyond the instrument-operation level, thereby allowing instrument operators and other scientific personnel in developing countries and CEITs to use their data, other available data, and models in both regional and international research areas. This should include:
  - Resources for the exchange of visits among personnel from monitoring stations in developed and developing countries and CEITs in order to ensure technology transfer and sustained measurement programmes.
  - Resources to permit the participation of representatives from developing countries and CEITs in regional and international validation and intercomparison campaigns.
- Provide resources to establish systems for public dissemination of information about the effects of ozone and UV changes on human health and the environment. This dissemination, which includes education and outreach programmes, is especially important in developing countries and CEITs. Network facilities, such as those of the UNEP Division of Trade, Industry and Economics (UNEP/DTIE), could be utilized for this purpose.
- Provide resources for the establishment of regional centres for research, calibration, and validation in developed and, especially, in developing countries.
- Urge the Parties to extend the life of and make contributions to the Trust Fund for Observation and Research (established by Decision VI/2). This fund is critical to enabling the capacity-building activities that have been highlighted above. Presently, this fund is far short of satisfying these needs.

12. OTHER MATTERS

No other matters were raised for discussion.

13. CLOSURE OF THE MEETING

Mr Kurylo, after thanking all participants for their attendance and hard work, declared the meeting closed at 4 p.m. on Wednesday, 21 September 2005.
ANNEX A

SIXTH MEETING OF THE OZONE RESEARCH MANAGERS
OF THE PARTIES TO THE VIENNA CONVENTION
FOR THE PROTECTION OF THE OZONE LAYER

19–21 SEPTEMBER 2005
VIENNA, AUSTRIA

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AGENDA

1. Opening of the meeting.

2. Organizational matters:
   (a) Election of the Chair;
   (b) Adoption of the agenda.

3. Review of the recommendations adopted at the fifth meeting of the Ozone Research Managers\(^1\), and the resulting decisions of the sixth meeting of the Conference of the Parties to the Vienna Convention for the Protection of the Ozone Layer\(^2\), in particular decision VI/2.


7. World Climate Research Programme project on “Stratospheric Processes and their Role in Climate” (SPARC).

8. Science, environmental effects and technology and economic assessments under the Montreal Protocol:
   (a) Status and plans for the 2006 assessment;
   (b) Special report by the Intergovernmental Panel on Climate Change and the Technology and Economic Assessment Panel on safeguarding the ozone layer and the global climate system.

9. National reports on existing and planned activities relating to ozone research and the monitoring, calibration and archiving of measurements; and on UV-B monitoring and initiatives aimed at the prevention of UV-B and sun-related injuries.

\(^1\) Held in Geneva, Switzerland, from 25 to 27 March 2002. For the report of the meeting, see the World Meteorological Organization’s Global Ozone Research and Monitoring Project Report No. 46 of March 2002.

\(^2\) Held in Rome, from 25 to 29 November 2002. For the report of the meeting, see document UNEP/OzL.Conv.6/7.
10. Information on the organization of events to celebrate the twentieth anniversary of the Vienna Convention and on the holding of the sixth meeting of the Conference of the Parties to the Vienna Convention, the seventeenth meeting of the Parties to the Montreal Protocol and associated meetings.

11. Adoption of the recommendations and the report.

12. Other matters.

13. Closure of the meeting.

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National Reports available to the meeting:

Argentina  
Armenia  
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Philippines  
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Russian Federation  
Slovakia  
South Africa  
Spain  
Switzerland  
Turkey  
Turkmenistan  
United Kingdom  
United States of America  
Uzbekistan  
Vietnam
ARGENTINA

The Argentine Republic is one of the very few countries whose southern territories come, each spring under the direct influence of the Antarctic Ozone Hole. Furthermore its northwestern territories, at the edge of the Andes Altiplano, register some of the highest levels of UV radiation in the world. Thus ozone and UV monitoring as well as scientific research in the field are very relevant to its society, despite budget limitations. In recent years the developing evidence demonstrating the existence of ozone-climate interactions has become a growing concern. The present report is an update of the previous one and spans the period 2002-2005.

OBSERVATIONAL ACTIVITIES

A number of institutions in Argentina carry out observational activities, measuring stratospheric ozone, ultraviolet radiation as well as other relevant chemistry and dynamics. Primary operational monitoring is carried out by the Servicio Meteorológico Nacional (S.M.N.), Various research institutions (Consejo Nacional de Investigaciones Científicas y Técnicas – CONICET -, Instituto Antártico Argentino – IAA -, Centro de Investigaciones de las Fuerzas Armadas – CITEFA -, Comisión Nacional de Actividades Espaciales – CONAE -, national and private universities) are also involved in monitoring and campaign activities. Furthermore there are other ozone related activities, referred to tropospheric ozone and biomass burning which are also relevant due to possible impact of biomass burning, e.g. methyl bromide production and nitrogen oxides, during severe convection in the subtropics, which can impact ozone in the lower stratosphere.

Column measurements of ozone and other gases/variables relevant to ozone loss

The SMN carries out column ozone operational measurements using Dobson instruments at:

<table>
<thead>
<tr>
<th>Station</th>
<th>Location</th>
<th>Since</th>
<th>Last calibration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buenos Aires</td>
<td>34°35'S-58°29'W</td>
<td>Jan. 1966</td>
<td>December 1999</td>
</tr>
<tr>
<td>Com. Rivadavia</td>
<td>45°47'S-67°30'W</td>
<td>Sep 1995</td>
<td>December 1999</td>
</tr>
<tr>
<td>Base Marambio</td>
<td>64°14'S-56°43'W</td>
<td>Sep. 1987</td>
<td>August 2001</td>
</tr>
</tbody>
</table>

The AFO (Automatic Filter Ozone) network, operated conditionally at the following sites:

<table>
<thead>
<tr>
<th>Station</th>
<th>Location</th>
<th>Since</th>
<th>Instrument No Last Calibration</th>
</tr>
</thead>
<tbody>
<tr>
<td>La Quiaca</td>
<td>22°06'S 65°06W</td>
<td>Oct. 1998</td>
<td>AFO 7- Sep. 1998</td>
</tr>
<tr>
<td>San Julián</td>
<td>49°19'S-67°45'W</td>
<td>Oct 1998</td>
<td></td>
</tr>
</tbody>
</table>

Due to problems with spare parts and maintenance supplies, which are not attributable to the SMN, these instruments are currently out of operation.

The Instituto Antártico Argentino operates the following instruments, primarily through various international cooperation agreements (Spain, Italy):

<table>
<thead>
<tr>
<th>Station</th>
<th>Location</th>
<th>Instrument</th>
<th>Since</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgrano II</td>
<td>77°52'S 34°37'W</td>
<td>Brewer MKIV</td>
<td>1992</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EVA (DOAS)</td>
<td>1996</td>
</tr>
<tr>
<td>Marambio</td>
<td>64°14'S 56°37'W</td>
<td>EVA (DOAS)</td>
<td>1994</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NEVA spectrograph</td>
<td>2003</td>
</tr>
<tr>
<td>San Martín</td>
<td>68°08'S 67°08W</td>
<td>Brewer MKIV</td>
<td>2002</td>
</tr>
</tbody>
</table>
Profile measurements of ozone and other gases/variables relevant to ozone loss

**Ozonesondes**

Ozone and temperature profiles are obtained at Marambio, Antarctica, using ECC ozonesondes. This is carried out in cooperation with the Finnish Meteorological Institute since 1988. The original programme which included 40 ozonesonde launches per year has been upgraded this year to more than 50 per year. Ozone and temperature profiles are also obtained at Belgrano II, Antarctica, using ECC ozonesondes, approximately 70 per year, since 1999.

**Lidars**

Ozone profiles are being obtained at Río Gallegos (Lat: 51° 55’ S), using the DIAL technique. This containerized instrument has been recently completed at CEILAP (Centro de Investigaciones Laser Aplicados), CITEFA/CONICET, and transported to its current site with a full complement of instruments (2 lidars for water vapour and stratospheric aerosol) and a set of meteorological instruments with the support of JAICA (Japan). For further information, including the international participants as well as updated results refer to [www.division-lidar.com.ar](http://www.division-lidar.com.ar).

A Lidar system operates at CEILAP (Buenos Aires) to monitor atmospheric aerosols. It can simultaneously monitor the whole troposphere (starting from 50 m) into the lower stratosphere (under 30 km). It measures in real time the following atmospheric parameters: the atmospheric boundary layer (ABL), tropospheric aerosols optical parameters (radiative properties), stratospheric aerosols, the tropopause height evolution and cirrus clouds evolution (backscatter coefficient and optical depth statistics).

**UV Measurements**

**Broadband Instruments**

The main broadband network is operated by the S.M.N.: Solar Light at Buenos Aires, Uhuiaia, Marambio and for some years at Pilar. YANKEE at Pilar and La Quiaca.

All these instruments operate since the setup of the National UV Monitoring Network in 1995.

Regular measurements made are with a YES Biometer (erythemal irradiance meter), also belonging to the network, located and operated by the Observatorio Astronómico and Solar Radiation and Atmospheric Physics Group, Institute of Physics of Rosario - IFIR (Universidad Nacional de Rosario/CONICET, approx. 400km north of Buenos Aires).

Furthermore IFIR also has an EKO Biometer and an EKO UVA solarmeter, presently located in Southern Patagonia, to study the influence of the near vortex (and ozone hole) edge on solar UV irradiances and related biological actions over the Argentine continental territory.

**Narrowband filter instruments**

The IAA operates the following instruments at the Argentine Antarctic Stations:

UV NILU instruments, at Marambio and Belgrano II, since 1993.
At CEILAP (Buenos Aires) measurements are made with the following instrument array:
UVB – MS-210D, EKO Radiometer (190 nm to 290 nm) with erythemic doses.
UVA – MS-210A, EKO Radiometer (290 nm to 400 nm).
GUV-541 Biospherical Inst. Inc.
CIMEL sun photometer measuring at 1200, 940, 870, 670, 500, 440, 380, 340nm
**Spectroradiometers**

The IAA operates the following instruments at the Argentine Antarctic Stations:


Periodic measurements are made with a Monospec 27 UV-Vis spectroradiometer with UV CCD detector at specific periods during the year. At present this instrument operates at CEILAP, Buenos Aires.

**Calibration Activities**

Dobson instruments are calibrated at the S.M.N. Observatorio Central Buenos Aires (Villa Ortuzar) since the Buenos Aires Dobson is the regional reference instrument. WMO Region III TECO as well as those belonging to the national network (Ushuaia, San Julian, Pilar an La Quiaca) are also calibrated at Observatorio Central with the TECO reference instrument.

The Solar Radiation and Atmospheric Physics Group at IFIR (CONICET – National University of Rosario) is responsible for the scientific advice and calibration of the Argentina UV Monitoring Network together with the SMN.

**RESULTS FROM OBSERVATIONS AND ANALYSIS**

Much work has been done in the analysis of local/regional/hemispheric observations, satellite retrievals (in particular TOMS) and reanalysis products (NCEP and ECMWF). The latest works are listed in section 4.3 below. Combined studies have been carried out relating ozone with UV, and ozone with atmospheric variables on dynamic and climatic scales. Work has been carried out the Departamento de Ciencias de la Atmósfera, University of Buenos Aires (UBA), and at Programa de Estudios de Procesos Atmosféricos en el Cambio Global (PEPACG, Pontificia Universidad Católica Argentina/CONICET) studying the relationship between tropospheric, tropopause and stratospheric dynamics and ozone evolution. Such work includes two PhD Theses, which were successfully defended at UBA, as well as a number of MSc. Thesis in Physics and Atmospheric Sciences.

*Figure from Malaca et al. (2005) showing the cubic polynomial fit to 20 years of TOMS total ozone annual mean values (solar cycle and QBO contributions removed) at two southern latitudes for various longitudes.*

The IFIR Group, in collaboration with the University of Innsbruck, Austria, the Argentina Skin Cancer Foundation and the Argentina National Weather Service, developed the UV index for clear and cloudy conditions for all the country. A thorough UV climatology, both under clear sky and cloudy conditions, for Argentina was developed as part of a PhD Thesis at Universidad Nacional de Rosario.
THEORY, MODELLING AND OTHER RESEARCH

Theoretical and modeling work has taken place IFIR, UBA and PEPACG. The latter group is cooperating with University of Reading (U.K.) in the development and application of an adaptive grid Chemistry Transport Model, called Adaptive Mesh Refinement or AMR-CTM, which is currently a 2-D model whose resolution adapts locally in order to better solve the evolving stratospheric features. Also included in this work is an interaction with Max-Planck Institut fur Atmospheric Chemie, University of Mainz, in order to install in the AMR-CTM the MECCA-MESSY Chemistry module. Work is under way with the AMR-CTM to understand the evolution of the vortex edge during the 1999 APE-GAIA Campaign, together with Università Degli Studi l’Aquila (Italy) as well as to analyze the behaviour of the 2002 anomalous ozone hole with regards to the tropospheric dynamics of the period. Further work includes the development of a 2-D and 3-D trajectory code.

Work at UBA includes extensive climatology studies of Southern Hemisphere stratospheric and tropospheric variables, in order to understand the mechanisms involved in the dynamic and climate coupling of these two regions and their relation to ozone change.

Work at IFIR includes the following topics:

- Radiative transfer model calculation of UV solar radiation and biological actions with the TUV programme (developed by S.O. Madronich at NCAR, www.acd.ncar.edu/TUV )

- Sensitivity studies of the influence of Biologically Active UV Radiation to Stratospheric Ozone Changes: Effects of Action Spectrum Shape and Wavelength Range.

At the Facultad de Ciencias Químicas de la Universidad Nacional de Córdoba, lab research is carried out on the chemical behaviour of minor species and species derived from CFC replacements.

DISSEMINATION OF RESULTS

Data Reporting

The SMN sends total ozone measuremments from Buenos Aires, Ushuaia, Salto (Uruguay), Comodoro Rivadavia and Marambio routinely to the WOUDC. THE AFO retrievals, when the instruments operated were also submitted there. Ozonesonde data are also submitted to the WOUDC. The database is currently being transformed to the required CSV format. Surface ozone retrievals are submitted to the corresponding centre in Japan.

Information to the public

As mentioned above, the Argentine society is sensitive to ozone and UV related issues. Thus providing information and scientific results is part of the activities of SMN as well as of researchers in the field. Since 200, the SMN provides a national UV forecast both in its webpage as well as to the national media. Indeed the IFIR Group, in collaboration with the University of Innsbruck, Austria, the Argentina Skin Cancer Foundation and SMN, developed the UV index for clear and cloudy conditions for all the country.

Furthermore, IFIR, UBA and PEPACG provide information to the media. During the ozone hole season PEPACG sends to the media every fortnight a report describing the ozone hole evolution using satellite retrievals and meteorological information. It is interesting to note that the information provided by the Argentine scientists has reached media in the Spanish speaking world. Furthermore primary and high school students, because of these reports contact research groups to get more information for school projects, etc.
Figure showing the UV forecast products available at the SMN webpage.

Relevant Scientific papers 2002-2005


- Piacentini, R.D., Cede, A., Bárbara, H. Extreme solar global and UV irradiances due to cloud effect measured near the summer solstice at the high altitude desertic plateau Puna of Atacama. Journal of Atmospheric and Solar Terrestrial Physics, 65, 727-731, 2003.


PROJECTS and Collaboration

As mentioned above, many of the monitoring and research activities are carried thanks to bilateral and international collaboration. Instruments are being operated thanks to agreements with the Finnish Meteorological Institute as well as with INTA (Spain), CNR/IFA (Italy), JAICA (Japan).

SMN cooperates with the Dirección Nacional del Antártico (DNA) and INTA (Spain) in the training of the ozonesonde operators and scientists bound for Belgrano II Antarctic Station.

Research cooperation takes place in a number of ways, for example through the direct involvement in projects such as EU’s SCOUT-O3. Part of the interactions takes place via bilateral agreements between research groups in Argentina and in other countries, such as Italy, France, Chile, etc. These bilateral agreements only fund travel but no research expenditures. The Inter American Institute for Global Change research has proved in the past an interesting tool for funding regional research and cooperation, but again the last calls for research projects were more oriented towards network development and meeting organization than specific research funding. Much of the international and regional cooperation takes place at a scientist to scientist level without formal institutional agreements. Such cooperation includes model and data exchanges. National projects are funded through CONICET and ANPCyT (Agencia Nacional de Investigaciones Científicas y Tecnológicas). While such funding is essential for functioning of research group and basic computational needs, it is very limited by comparison with funds available for research and monitoring in developed countries, and the amounts provided are too limited for experimental/monitoring equipment acquisition.

FUTURE PLANS

The current monitoring networks are to be maintained in operation.

A number of research activities are being considered and proposed for funding at the local level. Part of these will address issues relevant to the upcoming IPY. Some are already planned in regional and international cooperative efforts. Among the main research activities the following should be mentioned:

- Study of the influence of the near vortex and ozone hole regions in Patagonia
- Study the relationship between tropospheric and stratospheric dynamic and climatic behaviour and the links with ozone change.
- Ozone and climate change interactions.
- The chemistry and dynamics of Strat-Trop Exchange
- Cirrus clouds, the tropopause, and ozone.
- UV index development for different regions of South America (Brazil, Ecuador, Venezuela)
- Temperature increase as a result of global warming and UV effects on skin cancer development.
- Sustained monitoring with the containerized LIDAR system in Rio Gallegos.

NEEDS AND RECOMMENDATIONS

The Argentine Republic views with concern the international trend towards reducing funding and research on southern hemisphere ozone and stratosphere at mid and high latitudes. Much work needs to be carried out to understand many aspects of the ozone evolution and change, including ozone-climate relationships, particularly under the light of possible impacts of climate change, UV cloud relationships, etc., as well as to monitor ozone recovery.
In order to allow developing countries and countries with economies in transition to meet their commitments under the Vienna Convention and taking into account the lack of funds from other sources, it is crucial and urgent to make operative the Trust Fund established by decision VI/2 for the purpose of financing activities on research and systematic observation and to start providing funds for the activities identified as priorities. This includes, but is not limited to, the maintenance and calibration of the existing WMO Global Atmospheric Watch ground-based stations for monitoring column ozone, ozone profiles and ultra-violet radiation in those countries.

The Ozone Secretariat should be requested to raise awareness in potential donor countries on the importance of the Trust Fund, stressing the necessity of making annual contributions to it on a regular basis.

Specific needs

It would be highly convenient to replace the Marambio Dobson with a Brewer, which is far better suited for high latitude monitoring and can provide information on other variables as well as ozone. Thus an improved quality monitoring would be available there and the current Dobson instrument could be reallocated to a continental site, thus improving the coverage at southern mid latitudes.

International support is need to carry out sustained ozonesonde operation at Comodoro Rivadavia, thus providing very valuable ozone profile information at a southern hemisphere midlatitude site other than Melbourne, particularly under the light of the longitude differences observed in ozone change reported above.

International support is needed to carry out monitoring of tropospheric and stratospheric trace species, for example by providing an FTIR instrument and technical support.

This report was prepared by Dr Pablo O. Canziani, on the basis of the information timely provided by the national institutions and research groups involved in Vienna Convention related monitoring and research activities.

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ARMENIA

OBSERVATIONAL ACTIVITIES

Column measurements of ozone and other gases/variables relevant to ozone loss.

The measurements of the total ozone are produced on weather station "Arabkir" (40.1N, 44.3E; 1113m above sea level) since 1990 up to present time in city Yerevan by filter ozonemeter M-124. Since 2000 up to present time the measurements of total ozone (method DS-observations, ADADA wavelengths) are produced also on the south slope of mountain Aragats (40.3N, 44.1E; 2070m a.s.l.) on the regional station #410 of global ozone observation system, created on the weather station "Amerd" (fig.1) and equiped with Dobson-spectrophotometer D-044. In addition, there is a reserve station for ozone observations on the high-mountain weather station "Aragats" (40.3N, 44.1E; 3227m a.s.l.), equiped with ozonemeter M-124. There are also short-term experimental synchronous observations on weather stations "Arabkir", "Aragats" and "Sevan" (40.3N, 45.1E; 1927m a.s.l.) in the basin of Sevan Lake. The measurements of other gases are not produced.

Profile measurements of ozone and other gases/variables relevant to ozone loss

The regular measurements of the vertical distribution of ozone were not produced. There are several experimental Umkehr-observations on weather station "Amerd", as well as results of data processing the synchronous measurements on different-by-height weather stations "Aragats", "Sevan" and "Arabkir".

UV measurements - not produced.

Calibration activities

At June 2004 the calibration of D-044 at the European Regional Dobson Calibration Center (RDCC/E) at Hohenpeissenberg within the regular calibration schedule was executed.

RESULTS FROM OBSERVATIONS AND ANALYSIS

The results of the observations were submitted for Figure 2.

THEORY, MODELLING, AND OTHER RESEARCH

For study of UV effect, the statistical model, linking the skin cancer morbidity of population with UV irradiation is created in the following regions of Armenia: city Yerevan (altitude 1.1–1.2 km a.s.l., town population), Ararat Valey (altitude 0.9–1.0 km a.s.l, rural population) and basin of Sevan Like (altitude around 2km a.s.l., rural population). Main results: the dependency of health criticality of the above mentioned groups of the population towards influence UVR depending on lifestyle and heights of terrain is explored.
DISSEMINATION OF RESULTS

Data reporting

The results of the total ozone measurements are monthly sent to the WOUDC.

Information to the public

Since 2002 on the basis of the information about UV-indexes provided by the Institute of Biological Physics and Biostatistics, University of Veterinary Medicine Vienna (http://i115srv.vuwien.ac.at/uv/uv-index/uvieue.txt) and according to the recommendations of COST-713 Action "UVB Forecasting" is daily calculated and published through mass media forecasts for UV-indexes for mostly inhabited areas of Armenia.

The meanings of UV-indexes for Armenia are in-group of the highest for Europe.

Relevant scientific papers

In 2001 was issued [1]. Results of the research of effects UV irradiance are published in [2].

PROJECTS AND COLLABORATION

At present no international and national projects on study of ozone are conducted.

The national project on study of the solar radiation mode for 1980-2004 has just been started.

Execution of Dobson-programme is being implemented with assistance of DWD (Germany) and SOO CHMI (Czech Republic).

FUTURE PLANS

The testing of new instrument - the UV-meter, developed by Institute of the Applied Problems of Physics of Armenia.

NEEDS AND RECOMMENDATIONS

The capacities of weather station "Amberd" allow performing of national and international projects on monitoring of solar radiation, UV climatology, profiling of vertical distribution of ozone with balloon sondes, lidar observations of the composition of atmosphere, transboundary pollution in region of South Caucasus.

References


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BELARUS

A number of significant amendments to the Law of the Belarus Republic for Ozone Layer Protection, adopted in 2001, were introduced by the National Assembly of Belarus in October 2004. Ozone monitoring was determined as a part of National Environmental Monitoring System (NEMS). A plan for the development of the Atmosphere Ozone Monitoring subsystem up to 2010 has been prepared. Decision of Belarus Government N 949 dated the July, 14 2003 pronounced the Ministry of Education responsible for ozone monitoring in Belarus.

OBSERVATIONAL ACTIVITIES

In accordance with decisions of the Sixth Meeting of the Conference of the Parties to the Vienna Convention, Belarus has continued to construct instruments and develop monitoring, calibration and archiving of stratospheric and tropospheric ozone, aerosols, and surface UV radiation data.

Column measurements of ozone

Total ozone measurements are carried out at an Ozonometric station (Woudc identification N 354) located in Minsk at the National Ozone Monitoring Research & Education Center (NOMREC). The Station coordinates are (53.833N, 27.469E). The daily measurements are implemented with the ultraviolet multi-wavelength spectrometer-ozonometer PION. The total ozone amounts are also retrieved via intensity ratios of pairs of wavelengths using Stamnes tables from the observation of horizontal UV irradiance measured with spectroradiometer PION-UV. The both instruments constructed at the Belarus State University.

Profile measurements of ozone and aerosols

Profile monitoring of ozone concentrations and stratospheric aerosol executes by means of Dial lidar with working wavelength 308 and 355 nm up to 35-40 km. Routine measurements are carrying out three times per month on average at the Institute of Physics of National Academy of Sciences (IPNAS), Minsk (see Figure 1).

![Ozone concentration profiles, Minsk, 2004](image)

*Figure 1: Ozone concentration profiles during negative ozone anomalies in 2004, winter period. Solid line - Middle profile for winter period.*
UV measurements

Regular measurements of irradiance in the spectral range 285-450 nm are carried out at the Ozonometric station (NOMREC, Minsk) with the portable UV spectroradiometer PION-UV since September 2001. The automated instrument PION-UV registers more than a hundred global/diffuse UV spectra per day. Simultaneously controlling programme calculates UV-index and daily doses of biological effects.

Calibration activities

Spectrometer-ozonometer PION was inter-compared with a WMO regional standard (Dobson N 108 spectrometer) in St.-Petersburg (Russia, August 2001). NOMREC consistently develops and successfully introduces in practice a concept of self-calibration of the net ozonometers. This means carrying out all available calibration procedures mainly on the base of results of measurements and testing made during operation cycle of the instrument and excluding any laboratory testing and inter-comparisons. Now following procedures are available:

- testing and correction of the extraterrestrial parameters for total ozone calculation by analysis of the diurnal total ozone trends;
- testing and correction of the wavelength setting;
- Langley absolute calibration of the spectrometer.

Calibration testing of the current instrument’s parameters is performed in NOMREC using special calibration bench with band-lamp certified by Russian National Standard Agency in spectral range 285 – 1200 nm.

RESULTS FROM OBSERVATIONS AND ANALYSIS

The annual average total ozone value above Belarus in 2004 was lowest for all period of ground-based observations (1997-2004). In the second half of 2004 from middle of July till December the total ozone deficit above Belarus territory was about 5%. In the first half of 2005 the total ozone deficit above Belarus has increased up to 7 %. Occurrence of the «mini-hole» has been observed in unusual for Belarus period of time – beginning of September and the end of May.

The analysis of surface air temperature and total ozone data has shown that the daily total ozone and surface air temperature values are correlated (for summer in Belarus, see Figure 2). This interconnection has been taken into account in the UV index forecast technique.

Figure 2: Daily values of surface air temperature and total ozone (smoothed by 4 point moving average).
THEORY, MODELLING, AND OTHER RESEARCH

An improved multi-wave variant of algorithm on vertical ozone profile retrieval from Umkehr measurements has been developed to update the ozonometer PION controlling programme.

A theoretical method to improve the technique of “direct-sun” Aerosol Optical Depth measuring in the UV spectral range has been proposed.

The Langley-procedure accuracy for “direct-sun” UV devices has been estimated and a method to avoid the clouds disturbance has been implemented.

Epidemic studies carried out in collaboration of NOMREC and Belarus Sanitary & Hygiene Research Institute (BSHRI) have demonstrated that the incidence of skin cancer in Belarus has been increasing rapidly over the last 10 years. Incidence of melanoma in 1993 was 3,0 per 100000 and increased to 4,56 in 2002, incidence basal cell carcinoma (BCC) increased from 19,96 to 35,57, and squamous cell carcinoma of skin (SCC) from 4,29 to 8,45.

DISSEMINATION OF RESULTS

Data reporting

The total ozone data are submitted to the World (Canada) and CIS (Russia) data centers. UV monitoring was carried out from September 2001 with the PION-UV spectroradiometer. But some calibration problems prevented us to put our surface UV spectra at WMO’s disposal. In 2005 year the spectroradiometer PION-UV was recalibrated using the new Russian National UV Source Standard. Now results obtained are recalculating and soon NOMREC will be ready to send data to WOUDC and other centers regularly (in real time mode if necessary).

Information to the public

Short-term UV index forecast (both for cases of clear sky and with forecasted cloudiness taken into account) are daily submitted to Belarus Telegraph Agency and to national daily newspaper “Zvyazda” (about 50 000 numbers daily).

Also these values are presented at NOMREC Internet site http://www.nomrec.bsu.by.

PROJECTS AND COLLABORATION

There are 6 federally funded national projects on ozone, UV radiation and tropospheric ozone. These projects are coordinated by NOMREC. Main topics are:

- Ozone mini-holes dynamics and climate parameters.
- Stratospheric and surface ozone interaction.
- DOAS instruments development.
- Stratospheric ozone and aerosols lidars.
- UV radiation level and human health.

Ozone and aerosols investigations are carried out in collaboration with Lidar Station of IPNAS. Lidar investigations of ozone layer are implemented in the frame of CIS-LiNet (lidar network in CIS countries) activity.
FUTURE PLANS

Five new UV irradiance monitoring stations will be put into operation next 5 years.

New zenith observation instrument is developed for nitrogen dioxide total amount and profile retrieval in NDSC standard. It will be put into operation on NOMREC Ozonometric station aiming to be included into NDSC.

Developed theoretical models, software, and optical tool kit allow us to participate in international projects on validation of satellite spectral measurements and ozone/aerosol retrieval algorithms.

Planned activity on the atmospheric aerosol investigation includes theoretical modeling and realization of Sun-Aureole UV experiments aiming the aerosol micro-characteristics retrieval.

UV index mapping and differential forecast will be introduced in 2006.

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BELGIUM

OBSERVATIONAL ACTIVITIES

The main research institutes that are currently involved in ozone/UV and ozone related observations include: the Royal Meteorological Institute (KMI-IRM), the Belgian Institute for Space Aeronomy (BIRA-IASB) and the Université de Liège (ULg) - Institute of Astrophysics and Geophysics. The Université Libre de Bruxelles (ULB, Laboratoire de Chimie Physique Moléculaire) is providing the laboratory support for analysing spectra.

Column measurements of ozone and other gases/variables relevant to ozone loss

The Royal Meteorological Institute (KMI-IRM)

Continuation of regular ozone column measurements with two automated Brewer spectrophotometers (Nrs 16, 178) and one Dobson instrument (Nr 40) is a single monochromator, in use since 1983 and the other one (Nr 178) is a double monochromator installed in 2001. All these instruments are operated at Uccle (50.8°N, 43.5°E, 100 m asl), a complementary NDSC station and station 053 in the WOUDC list.

Profile measurements of ozone and other gases/variables relevant to ozone loss

University of Liège (ULg)

Continuation of infrared solar observations at the International Scientific Station of the Jungfraujoch (ISSJ - Primary Alpine NDSC Station in the Swiss Alps 46.5°N, 8.0°E, 3580 m asl) using wide-band pass, very high spectral resolution Fourier transform Infra-Red (FTIR) instruments, which allow measuring multiple species, simultaneously. Geophysical parameters consist in total- and more recently- in distinct partial tropospheric and stratospheric column abundances above the site. Table 1 lists the atmospheric gases which have been studied routinely at the Jungfraujoch.

Table 1: Molecules currently studied in FTIR solar spectra recorded at the Jungfraujoch

<table>
<thead>
<tr>
<th>Reference gas:</th>
<th>N2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minor constituents:</td>
<td>CO2, N2O, CH4, CO, O3</td>
</tr>
<tr>
<td>Trace constituents:</td>
<td></td>
</tr>
<tr>
<td>Halogenated species:</td>
<td>HCl, ClONO2, HF, COF2,</td>
</tr>
<tr>
<td>CCl2F2, CHCIF2, CCl3F, CCl4, SF6</td>
<td></td>
</tr>
<tr>
<td>Nitrogenated species:</td>
<td>NO, NO2, HNO3</td>
</tr>
<tr>
<td>Others:</td>
<td>C2H6, C2H2, HCN, OCS, H2CO2,</td>
</tr>
<tr>
<td>H2CO (multi-month avg.,)</td>
<td></td>
</tr>
</tbody>
</table>

The Royal Meteorological Institute (KMI-IRM)

The vertical distribution of ozone continues to be measured three times per week by means of balloon soundings with ECC ozone sensors, since 1997; Brewer-Mast sensors were used during the 1969-1997 period.

1 no input was received from the Université Libre de Bruxelles (Dr M. Carleer) nor from the University of Antwerp (Dr Deckmyn)
2 http://www.ndsc.ws
3 Species typed in italic are primarily present in the stratosphere, while the others are tropospheric source gases.
The Belgian Institute for Space Aeronomy (BIRA-IASB)

Monitoring of O₃ and interacting species (halogens, NOₓ, BrO, HCFC, CFC…) for budget and long-term trend studies, continues to be performed at:

- the International Scientific Station of the Jungfraujoch, Switzerland: FTIR and SAOZ instruments. SAOZ measures O₃ and NOₓ columns in the UV-Vis spectral range, since 1990. They complement the FTIR time series produced by ULg summarised in 1.2.1. An additional MAXDOAS Instrument will be installed at the Jungfraujoch in late 2005.
- Harestua, Norway, 60°N, 11°E: UV-VIS DOAS instruments, since 1994 (O₃, NO₂, OCIO, BrO)
- the Observatoire de Haute Provence (OHP), France, 44°N, 8°E: UV-VIS DOAS instrument (O₃, NO₂, BrO columns), since summer 1998. The UV-VIS DOAS instrument has been upgraded
- with an off-axis capability (MAXDOAS) in 2000 and since then provides also tropospheric abundances of O₃, NO₂, BrO, and H₂CO.
- at Ile de la Réunion (22°S, 55°E): UV-Vis MAXDOAS instrument (O₃, NO₂, BrO, H₂CO columns and tropospheric abundances), starting in summer 2002. Campaigns with a mobile Fourier-transform infrared (FTIR) instrument have been conducted in Sept-Oct. 2002, and August to November 2004. Permanent FTIR measurements at Ile de la Réunion are planned, starting in 2008. During the first FTIR campaign at the Ile de La Réunion, simultaneous measurements at sea level and at high altitude (2200 m asl) were performed, allowing to infer columns in the boundary layer/low troposphere, via a differential approach.

UV measurements - spectroradiometers

The Royal Meteorological Institute (KMI-IRM) - The Belgian Institute for Space Aeronomy (BIRA-IASB)

- UV spectral irradiance measurements at Uccle: both Brewer spectrophotometers are also used to monitor the UV-B radiation intensities. They perform several scans per day (number depending on the time the sun is above the horizon)

Calibration activities

The Royal Meteorological Institute (KMI-IRM)

- The Dobson instrument was last calibrated at the Regional Calibration Centre of WMO in Hohenpeißenberg in 2000. Since then the monthly calibration tests with standard and mercury lamps showed that the instrument remains stable.
- The Brewer instruments were compared with the travelling reference instrument in 2003. The results of this calibration were taken into account for the new ozone observations and also the older data were recalculated.
- The ozone sondes are carefully prepared and a correction procedure is applied to minimise the inhomogeneity that could have been introduced at the change of the sonde type in 1997.
- The UV-B calibration level was checked with 1000W lamps in 2003 during the calibration visit. In 2004 the special comparative observations were performed with a travelling reference UV instrument of the Joint Research Centre (JRC in Ispra) in the frame of the Qasume project (Gröbner et al, 2004). This showed that the calibration based on the monthly tests with 50W lamps was within the expected errors.
The Belgian Institute for Space Aeronomy (BIRA-IASB)

The observations are all contributing to the NDSC and are being certified in this framework. Only for the measurements at the Ile de La Réunion, the NDSC qualification has not yet been solicited. But the quality of the spectral data has been verified by performing daily HBr cell measurements for controlling the instrument’s alignment, as recommended by the NDSC IRWG (Infrared Working Group).

The MAXDOAS instruments have participated to several calibration campaigns, e.g., in Andoya in winter 2003, in the EC project FORMAT, and recently (summer 2005) in the Dandelions campaign in Cabauw (NL).

University of Liège (ULg)

Calibration of the Jungfraujoch FTIRs is performed according to recommendations in related NDSC protocols. This is done regularly by using sealed cells containing known amounts of either HBr or N₂O gases, which allow characterising the instrumental line shape. In addition, atmospheric gases whose vertical distributions and concentrations are well known (i.e., N₂ and CO₂) are used to check the overall instrumental performances and their long-term stability.

RESULTS FROM OBSERVATIONS AND ANALYSIS

The Royal Meteorological Institute (KMI-IRM)

Research evolution of total atmospheric ozone and its distribution versus altitude at northern mid-latitudes, in particular above Belgium revealed a mean temporal decrease in ‘good’ ozone in the stratosphere and an increase in ‘bad’ ozone in the troposphere. With the help of model calculations it was shown that both changes are primarily of anthropogenic origin. Further observations in Uccle (Brussels) showed that observed levels of harmful UV-B irradiance at ground level anti-correlate with levels of stratospheric ozone. Initiatives have been taken to warn the general public about health risks resulting from excessive exposure to the sun in summertime.

The figure below shows the time evolution of the ozone column over Uccle based on the combined data from Dobson and Brewer instruments (1990-now). The ozone column decreased by 3% per decade in the period 1980-1997, with a likely sign of recovery afterwards, although the period is too short to draw firm conclusions. According to the Uccle soundings, the decrease occurred in the lower stratosphere, especially during winter and early spring. In the troposphere, on the contrary, the ozone concentrations tend to increase due to photochemical reactions in polluted air.

Figure 1: running annual mean of total ozone from Dobson and Brewer spectrophotometers at Uccle, together with a stepwise regression. The times of major volcanic eruptions, affecting the ozone layer are also indicated.
Based on monitoring, from aboard satellites, of stratospheric aerosol loading on a quasi-global scale, the spatio-temporal distribution between 12- and 35-km altitude has shown that aerosols are among the most varying constituents in the lower stratosphere, capable of exerting negligible to acute regional-scale effects on climate. In particular, major volcanic eruptions, like that of Mount Pinatubo (Philippines) in June 1991, enhance aerosol abundance significantly, worldwide. Belgian scientists were able to show that the aerosol increase following this event caused temporary depletion of stratospheric ozone above Uccle and of nitrogen dioxide over the Jungfraujoch. This is one example demonstrating the importance of simultaneous long-term monitoring of the particulate and gaseous composition of the stratosphere. Other important results are:

- Updated trends of stratospheric bromine
- Time series of O$_3$, NO$_2$ and BrO at the NDSC stations operated by BIRA-IASB (at Jungfraujoch since 1990; at Harestua since 1994; at OHP since 1998)
- Time series of OCIO abundances in Harestua, including model simulations.
- Global maps of BrO, SO$_2$, NO$_2$ from GOME and SCIAMACHY
- BASCOE 4D Var assimilation analyses
- Climatology of stratospheric aerosol; time series of vertical distributions of aerosol optical properties based on SAGE II data
- campaign data at Ile de La Réunion: vertical distributions of a large number of species measured by FTIR: O$_3$, HCl, HF, CO, N$_2$O, HNO$_3$, …; O$_3$, NO$_2$, SO$_2$, BrO distributions in the troposphere from MAXDOAS
- NO$_2$ vertical profile climatology

University of Liège (ULg)

- Consistent monitoring, since the mid-1980s, of the vertical column abundances above the Jungfraujoch, of HCl and ClONO$_2$, which are the main inorganic Cl$_y$ reservoirs in the stratosphere. Their sum shows that the rate of increase of Cl$_y$ has progressively slowed down during the early-1990s, and stabilised in 1996-1997, in response to the amended production regulations on O$_3$-depleting substances by the Montreal Protocol. Since, the Cl$_y$ loading has shown a slow but statistically significant decrease (-0.7 ± 0.2 %) over the 1998-2004 period, which is commensurate with the organic chlorine decrease in the troposphere.
- Monitoring of the evolution of anthropogenic chlorine-bearing source gases such as CFC-11, CFC-12, HCFC-22 and CCl$_4$ demonstrates the efficiency of the amended Montreal Protocol upon regulated versus unregulated ozone-depleting compounds.
- The O$_3$ column monitored from 1984 to 2004 shows that it has decreased by (4.5 ± 0.5) % during that 20-year period, with significant temporary perturbations that resulted from inter-annual variability and from the strong Mt. Pinatubo volcanic eruption in 1991.
- The most abundant NO$_y$ compounds (HNO$_3$, NO$_2$, NO, ClONO$_2$) show no statistically significant change in their total stratospheric loading. However, NO$_2$ reveals a rate of increase of (0.5 ± 0.2) %/yr which is consistent with similar investigations performed at the NDSC southern mid-latitude station of Lauder (N-Z).
- The continued rise, although having slightly slowed down during the past years, of the inorganic fluorine concentration in the stratosphere, contrary to the decrease of chlorine.
- Measured rates of increase of the major radiatively active gases that are to be controlled under the Kyoto Protocol;

THEORY, MODELLING, AND OTHER RESEARCH

The Royal Meteorological Institute (KMI-IRM)

The Brewer data have been analysed for aerosol information in the UV. These data are available now (Cheymol and De Backer, 2003).

The Belgian Institute for Space Aeronomy (BIRA-IASB)

**Modelling**

- Complete 3D modelling of the stratosphere, including transport, chemistry, aerosol micro-physics and a heterogeneous chemistry module
- Chemical 4D variational data assimilation, in particular of O₃
- 1D box model for process studies, and for interpretation of UV-Vis DOAS observations
- Studies based on 3D model IMAGES for the troposphere and UT/LS boundary region
- Development of inverse tropospheric modelling methods, to improve emissions estimates (e.g., for CO)

**Laboratory experiments**

- Spectroscopic studies in support of remote sensing experiments (optical spectroscopy, ion chemistry for mass spectrometry applications…)
- Spectroscopic studies in support of investigations concerning global warming issues
- Radiometric calibration for UV monitoring instruments
- Studies of reaction pathways and kinetics of atmospheric species, using mass spectrometry.

**Instrument developments**

- MAXDOAS instruments and associated data analysis algorithms; The MAXDOAS technique has the capability of determining vertical distributions in the troposphere and low stratosphere.
- BARCOS: a system for remote-control and automatic operation of a Bruker FTIR spectrometer for monitoring the atmospheric composition

**Retrieval algorithm developments**

- Recently developed algorithms have implemented the Optimal Estimation Method, and therefore allow the retrieval of vertical profile information from the ground-based DOAS and FTIR spectra, at low vertical resolution (worse than 5 km), for e.g., NO₂, O₃, HNO₃, HCl, ... For the FTIR data this approach has been optimised for some target species (incl. O₃) in the EC project UFTIR coordinated by BIRA-IASB.

**Satellite data retrievals**

- Development, validation and implementation of satellite data retrieval algorithms (e.g., for GOME and SCIAMACHY total O₃, NO₂, BrO, SO₂…; e.g. for aerosol and trace gases from GOMOS); data processing and dissemination
- Development of retrieval algorithms for IASI/Metop for aerosol and gases.

**Satellite data validation and characterisation**

- Continued contributions to the validation of ESA satellite data for O₃, NO₂, CH₄, CO, N₂O… (GOME, SCIAMACHY, GOMOS, MIPAS, ACE/SciSat …) using independent
ground-based data, mostly NDSC affiliated. This activity will be continued for OMI, GOME-2, IASI, ...

- Characterisation of the 4D information content of various satellite data, on the purpose of (1) integrating time series form successive satellite sensors (e.g., for \( \text{O}_3 \) total column and profile), remote sensing and in situ data from various platforms (ground, balloon, aircraft, satellite...) and, (2), developing observation operators for correct integration/comparison of satellite data with models.
- Development of climatologies of some stratospheric species like \( \text{NO}_2 \).

University of Liège (ULg)

Most of the research activities reported in the previous Ozone Research Managers Report (2002) are continuing.

**Satellite data validation and characterisation**

- Further exploitation of the ATMOS data (Atmospheric Trace MOlecule Spectroscopy, spanning the 1985-1994 period) as references for subsequent trend studies (e.g., the SciSat-ACE project (see below)) of over two dozen constituents present in the free troposphere and the stratosphere.

**DISSEMINATION OF RESULTS**

Data reporting

*The Royal Meteorological Institute (KMI-IRM)*

The ozone data (columns and profiles) are regularly deposited in the WOUDC of WMO. Uccle is also a complementary station for ozone in the NDSC. Therefore the data are also made available in that network. In near real time the data are also distributed via NILU, where the data can be used for campaigns (e.g. Match campaigns to determine ozone losses in the polar and sub polar winter atmosphere, see Streibel et al, 2005). The data are also stored and used in databases for the validation of satellite data (ENVISAT and EUMETSAT). Total ozone values are exchanged daily with the WMO ozone mapping centres in Canada and Greece for the production of daily ozone maps.

*The Belgian Institute for Space Aeronomy (BIRA-IASB)*

- Data concerning the chemical species are submitted to NADIR/NILU and NDSC/NOAA databases, as well as to the Envisat Cal/val database at NILU. UV-B data are in the SUVDAMA (EC) database.
- Spectroscopic laboratory data are submitted to international databases like HITRAN, GEISA, and via the institute Web page http://www.oma.be/BIRA-IASB/Scientific/Data/CrossSections/ CrossSections.html
- Project Web pages (see ‘Projects and collaboration’)

*University of Liège (ULg)*

- Series of NDSC-relevant molecules (e.g., HCl, ClONO\(_2\), HF, COF\(_2\), HNO\(_3\), NO\(_2\), NO, O\(_3\), CFC-12, HCFC-22) measured from 1989 to present, are being archived routinely at the NOAA Data Host Facility (Washington, DC, USA), with the ozone data mirrored to the WOUDC archive in

\(^{5}\text{http://sunset.astro.ulg.ac.be/girpas/).}\)

\(^{6}\text{http://remus.jpl.nasa.gov/atmosversion3/atmosversion3.html}.\)
Toronto. Pre-1989 data are available upon requests sent to the ULg scientists listed at the end of this report. Specific databases produced in support of European campaigns or for the validation of space-based sensors of the atmosphere are generally archived at NILU 7 (Norway).

Information to the public

The Royal Meteorological Institute (KMI-IRM)

- Daily UV forecasts are produced and disseminated with the weather forecasts. They are also available at the internet (www.meteo.be).
- Ozone and UV data of Uccle were also used in yearly reports on the environment (MIRA-T-2003, 2004, Polders et al, 2003, 2004).

The Belgian Institute for Space Aeronomy (BIRA-IASB)

- via participations to expositions, via Web pages 8
- BASCOE provides daily global O₃ forecasts via the Web9.

Belgian Federal Public Planning Service Science Policy (BELSPO)

The Belgian Public Planning Service Science Policy recently published an Assessment and Integration Report on Belgian Global Change research 1990 – 2002. It just one of the initiatives taken towards improved integration of research results into information relevant to policymaking10.

Final Reports of relevant research projects within the Scientific Support Plan for a Sustainable Development Policy can be ordered or downloaded from the BELSPO website11.

Relevant scientific papers

The Royal Meteorological Institute (KMI-IRM)

Peer reviewed:


7 http://www.nilu.no/
9 http://www.bascoe.oma.be
10 http://www.belspo.be/belspo/home/publindex


Other RMI publications related to the ozone research are available from: http://www.meteo.be/ozon/miscellaneous/publications.php

The Belgian Institute for Space Aeronomy (BIRA-IASB)

peer-reviewed


Other BIRA-IASB publications related to the ozone research are available from: http://www.aeronomie.be/nl.
University of Liège (ULg)


Other ULg publications related to the ozone research are available from: http://sunset.astro.ulg.ac.be/girpas/

PROJECTS AND COLLABORATION

Participation in other national and international collaborations projects

The Royal Meteorological Institute (KMI-IRM)

- satellite validation projects of ESA and Eumetsat.

The Belgian Institute for Space Aeronomy (BIRA-IASB)

- Belgian programme Scientific Support for Sustainable Development: ESAC-II: Experimental Studies of Atmospheric Changes II (2001-2005) (as coordinator)¹²
- IPCC Climate and WMO Stratospheric Ozone assessments

¹² http://www.oma.be/ESACII/Home.html
• 6th Framework Programme of the European Commission: GMES-GATO (finished Jan 31, 2005) GEMS, Evergreen\textsuperscript{13}, NOVAC, UFTIR\textsuperscript{14}, STAR\textsuperscript{15} SCOUT-O3, ACCENT (and its subproject AT2)...  
• ‘Chemistry and climate related studies using the IASI remote sensor’ for preparing the scientific research aspects of the IASI mission onboard METOP-1 (launch nominally 2005).  
• ESA GSE project PROMOTE  
• ESA study ‘Capacity’\textsuperscript{16}  
• Envisat Atmospheric Chemistry Validation Team, and SCIAVALIG

\textit{University of Liège (ULg)}

• IPCC Climate and WMO Stratospheric Ozone assessments

\textbf{Representation in international organisations}

\textit{The Royal Meteorological Institute (KMI-IRM)}

• COST 726  
• Brewer and Dobson scientific advisory groups of WMO  
• Advisory group for the Regional Brewer Calibration Centre for region VI (Europe)  
• EUMETSAT  
• Ozone-SAF  
• NDSC

\textit{The Belgian Institute for Space Aeronomy (BIRA-IASB)}

• WMO: UV-SAG (GAW)  
• SPARC/WCRP  
• NDSC (GAW/WMO) (co-chairmanship of UV-VIs, IR and Satellite Working Groups)  
• CEOS  
• SAG of GOME and GOME-2, GOMOS, SCIAMACHY, OMI  
• Atmospheric Science Panel (European Commission)  
• ESA council  
• Member of the Science Team of the Canadian ACE/SciSat mission  
• Member of EOS-Aura OMI International Science Team

\textit{University of Liège (ULg)}

• Atmospheric Science Panel (European Commission)  
• NDSC-Steering Committee,  
• IOC  
• GMES-GATO coordinating group.  
• Science Team of the Canadian SciSat-ACE project.  
• International Foundation of the ‘Hochalpine Forschungsstationen Jungfraujoch und Gornergrat, Switzerland.

\textsuperscript{13} [http://www.knmi.nl/evergreen]  
\textsuperscript{14} [http://www.nilu.no/uftir]  
\textsuperscript{15} [http://www.knmi.nl/samenw/star]  
\textsuperscript{16} [http://www.knmi.nl/capacity/]
Other collaborations

The Royal Meteorological Institute (KMI-IRM)

• with the Alfred Wegner Institute in Bremen for the Match Campaigns since the beginning of the 1990’s.
• with the Forschung Zentrum Jülich in Germany, and other National institutes performing ozone soundings for the setting up standard operating procedure for ozone soundings for WMO.

FUTURE PLANS

The Royal Meteorological Institute (KMI-IRM)

It is envisaged to stop the Dobson measurements and make an agreement with the University of Ile de La Réunion to loan the instrument to use it there to complete the NDSC capacities of that station

The Belgian Institute for Space Aeronomy (BIRA-IASB)

• Continuation of long-term NDSC observations at abovementioned stations
• Permanent FTIR and MAXDOAS measurements at Ile de La Réunion from 2008 onwards (nominally)
• Acquisition of a mini-MAXDOAS instrument for mobile measurements
• Acquisition of a CIMEL sun photometer, to be integrated in the Photons-Aeronet network
• Volcano monitoring with MAXDOAS instruments (EC project NOVAC)
• Participation in satellite experiments with ESA, Canada, EUMETSAT

Belgian Federal Public Planning Service Science Policy (BELSPO)

Within the programme ‘Science for a sustainable development (SSD)’ a first call for proposals was launched. One of the priorities relates to the interaction between atmospheric composition and climate change. The evaluation procedure is ongoing; projects are to start in December 2005.

Recurrent measurements at NDSC stations are mainly funded with multi-annual research budget. BELSPO is considering a more sustainable solution in cooperation with the federal scientific research institutes.

Belgium will open in 2007 a new scientific station in Antarctica

NEEDS AND RECOMMENDATIONS

• Needs to secure the financial support to continue long-term monitoring activities (including calibration of instruments, necessary equipment for ozone soundings) instruments and associated software upgrades,....) and data archiving and dissemination services.
CO-ORDINATES OF BELGIAN INSTITUTES AND LEADING SCIENTISTS INVOLVED IN O₃ RELATED RESEARCH AND OBSERVATIONS

University of Liège
Institute of Astrophysics and Geophysics
Dr E. MAHIEU (Data analysis, interpretation and archiving)
Prof. (Emeritus) R. ZANDER (Data analysis and interpretation)
Ph. DEMOULIN (Data analysis and observations)
Dr C. SERVAIS (Observations, and Instrumentation maintenance/development)
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Dr J. M. DE MAZIÈRE (Satellite and ground-based remote sensing measurements of the composition of the atmosphere, implementation and testing of retrieval algorithms to invert observations into geophysical data, remote-sensing instrument developments, data validation)
Dr M. VAN ROOZENDAEL (Satellite and ground-based remote sensing measurements of the composition of the atmosphere, implementation and testing of retrieval algorithms to invert observations into geophysical data, remote-sensing instrument developments, data validation)
Dr D. FONTEYN (Stratospheric modelling, 4D VAR data assimilation)
Dr J.-F. MULLER (Global tropospheric ozone modelling, inverse source/sink modelling)
Dr D. GILLOTAY Y (Ground- and space-based measurements of solar radiation: UV-B)
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BOLIVIA

OBSERVATIONAL ACTIVITIES

Column measurements of ozone and other gases/variables relevant to ozone loss

In Bolivia, there is only one station measuring the ozone layer. This station is run by the Atmospheric Physics Laboratory (LFA) at the Physical Research Institute (IIF) of the University of San Andres (UMSA), at La Paz.

Profile measurements of ozone and other gases/variables relevant to ozone loss

There is ozone column profile data from Umkehr measurements for three years, based on the Brewer data and using a standard atmospheric model.

UV measurements

Broadband measurements

From December 1995, when the laboratory started measurements, until May 1997, we were using a Solar Light 501 Biometer. Since July 1998, there are two YES broadband radiometers. One of the YES is kept fixed at the LAF, and the second is used for the field campaigns.

Spectroradiometers

The LFA has a special agreement with the Brazilian National Institute for Space Research (INPE) which allows the LFA to run the Brewer #110 at La Paz since 1996. There is a nearly continuous data series of the ozone layer depth from July 1996 to July 2004, when the equipment breakdown and was shipped back to Brazil for repair. It is schedule to be returned next September.

Calibration activities

One of the YES broadband radiometers was recalibrated at Innsbruck, Austria in 2002. Two intercomparison campaigns were held at the LFA. The first as an extension of the Argentinean calibration of the National network in year 2000, and the second during the Second Latin American Congress on Ultraviolet Radiation, with equipments from several countries.

RESULTS FROM OBSERVATIONS AND ANALYSIS

Several reports were written and published locally on the ozone layer trends measured at the LFA station in the outskirts of La Paz (16.5° S, 68.0 °W, 3200 m asl). Also there are studies comparing satellite-based data (from NASA’s TOMS) and our ground station, with a neatly fit. The main result from the analysis was the discovery of a small depletion of the ozone layer over the Bolivian high plateau (Altiplano) in relation to other locations at the same latitude. This effect was first attributed to the high altitude of the measuring station; as it misses the first three kilometers of the atmosphere, but more refined calculations shows that the “altitude effect” is not enough for account the difference, which has values around 15 DU.

One of the main findings was the discovery that the ozone layer at La Paz shows no large change when we compared the profiles obtained during two ozone-sounding-campaigns, one in 1963, and the second in 1998. Therefore, one can postulate that the ozone layer over the Bolivian Altiplano has remains unchanged for the last 40 years.
The main work of the LFA is on the solar Ultraviolet Radiation monitoring. Due a combination of several factors like, latitude, altitude, clear sky and open horizons; the Bolivian Altiplano receives very high UV doses, sometimes tagged as the highest in the world, with values above 8 kJ m\(^{-2}\) yr\(^{-1}\). The average UV Index at La Paz is 11, corresponding to 0.275 W m\(^{-2}\). Also, there is a seasonal dependence of the UV values, with the higher values on summer and lower at winter months. The climate favors our case in the sense that when the solar zenithal angles is minimum (even zero twice a year) usually correspond to the rainy season, and the cloud cover filters out a loot of the solar UVR. But, in the case of drought (as when ENSO appears) November becomes with clear skys and the UVI values jump out of the scale. We reported an exceptional value of (extrapolated) UVI = 23 for one day.

**THEORY, MODELLING, AND OTHER RESEARCH**

Aiming to get a better spatial coverage of the UVR in Bolivia, the LFA uses both the STAR model, and data from TOMS. The first is used to get an approximation of the UV irradiance in selected locations, to be contrasted with field-campaign data. These campaigns are carried out only for short periods, usually 3-5 days in each location.

In terms of modeling, there is a couple of works aimed to explain the “ozone anomaly” over the Bolivian Altiplano. Both works use TOMS and local data, and are based on the assumption that the ozone layer over the region is thinner due an effect of the gravity waves. The main hypothesis is that the air coming from the lowlands is trapped between the double chain of mountains, and the bouncing cause perturbations that in the end, erode the ozone layer. This is a permanent situation, contrasting to the seasonal “ozone hole” over Antarctica.

Another line of research is on the effects of the UV radiation over technological materials, on cultivable plants, on plankton and the food chain, and on the human health. On the first case, the LFA research focused on the effects of the high level of solar UVR in the Altiplano on the corrosion process of base metals exposed to the open environment. The main finding (yet to be confirmed) is a depletion of the corrosion rate of copper. A second line of research in this area is on the UVR effects on polymers, specially textile fibers (nylon and rayon), plastic sheets for greenhouses (Agrofilm™) and plastic bottles (PET). In the first case, we found that the damaging effects on the fibers depends more on the coloring treatment of the yarn than on the amount of UV absorbed by the fiber. In the second study, we found that the Agrofilm™ looses most of its good properties after being irradiated with 1 MJ of UVB. The films becomes almost opaque to the visible light, but allows a lot more (60%) of the UV radiation to come trough. The changes on the heat transmission properties are still under study, as the behavior of the PET bottles.

In the case of the cultivars, the LFA team worked with one of the most popular Andean cereals, the quinoa grain (*Chenopodium quinoa*, Wild.). We choose this plant by several reasons: it is a strong component of the Altiplano’s people, being the main protein source; it grows in the Southern Altiplano, which a region with very high UV levels, but at the same time is one of the poorest regions of the country, due its extreme aridity. We were exploring the relation of the UV exposure of the plant, and the protein and saponine content of the grain. Those substances are in competition inside the grain, the more saponine the plant develop, the less protein it has, and viceversa. A high content of saponine is bad news for the use of the grain as food, but is good for its industrial use. The main result of the study is that the high UV levels cause a delayed growing and maturation times, shifting the phenic stages. We could not get conclusive results on the saponine production as function of the UV irradiance due the lack of equipment (a spectrometer) and some other logistical problems.

The studies on plankton and UV were two fold. One side was carried out in the Titikaka lake, which is the highest navigable lake in the world (3860 m asl). Among the results of the campaigns we found that the phytoplankton has adapted it self to the very high solar UV levels producing a series of “sun screening” compounds, mainly of the mycosporine-acid type. The zooplankton did not produce this substance, but takes it from the phytoplankton and bioaccumulates it. The second stage was carried out several years later, in the First Bolivian
Scientific Expedition to Antarctica, merged to the Peruvian “XV Antar” when a similar study was taken, including the next step of the food chain: the krill. The result is also positive: the krill has the same UV-protecting substances as the zooplankton eaten by the crustacean, also keeping it by bioaccumulation.

Besides these activities, the LFA is also engaged in other research activities like air quality, air pollution monitoring, measurements of carbon dioxide and smoke from forest burning, climate change and their impacts on the ecosystems, etc.

DISSEMINATION OF RESULTS

Data reporting

The UV and ozone layer thickness values obtained with the Brewer are reported monthly to the INPE headquarters in Brazil for validation and later dissemination. This is done according the working agreement between our institutions. A copy of the data, in a booklet format is kept at the LFA and a second copy is given to the IIF library.

The UV data taken with other equipment (like the YES broadband radiometers) is available on request, and if the requester has not any commercial purpose, the LFA release the data for free.

Information to the public

The LFA is in charge to broadcast the UV Index on behalf of the Bolivian Ministry for Health. The UV Index is calculated from the measurements with several instruments at the LFA, and it is extrapolated for other cities in the country, or even neighboring countries (e.g Peru & Paraguay). As the weather forecast system in Bolivia is not very well developed (mainly due the complex topography of the country) the UV forecast is released as a table, with columns for three weather conditions: clear sky, cloudy, overcast; and rows for three skin types: I or Nordic, III or Mediterranean and V or dark. The forecast is released each day before noon, with the values for the next day, and it is transmitted to the media via fax and e-mail. Actually, the LFA is working with 2 national newspapers, 10 TV stations and 15 radio stations.

Also, as the LFA has been named as “National Institution of Reference” by the Pan American Health Organization (PAHO) and recognized as such by the Bolivian Ministry for Health, it has the task to monitor the UV levels in order to point out to the Ministry when to declare an “UV alert” which work in a similar way as the “epidemiological alerts”.

The LFA had published two books, the first one were the Proceedings of an International Seminar on Ultraviolet Radiation and the Ozone Layer, (R.Forno & M.Andrade, eds.1997) and the second book and a compendium of the activities around UVR in Bolivia during the LFA life (“La Radiación Ultravioleta en Bolivia”, F.Zaratti & R. Forno, eds. 2002) A Third volume is in press, with the activities during the PAHO-sponsored Technical Cooperation among Countries Programme between Peru and Bolivia (“TCC Peru – Bolivia, Activities Report”, D.Daza & E.R.Palenque, eds., 2005).

Relevant scientific papers

Among other publications, the next is a short list of the main results from the research activity at the LFA during the years 1996- 2004:


PROJECTS AND COLLABORATION

The LFA is a Collaborating Center for UV Radiation issues of the World Health Organization, since last year. This nomination comes as result of the successful experience of the LFA measuring and broadcasting the UV Index and carrying out the UVI campaign each year. This activity was the base for been named as “National Institution of Reference” by the Pan American Health Organization (PAHO) who sponsors a large share of the campaigns. In addition, the LFA was nominated as “Collaborating Center” by the WHO, for all the issues concerning UV radiation for the Andean Countries. These nominations represent a broader collaboration and, at the same time, more duties for the LFA for the research and dissemination on UV and its effects.

Besides the nominations by the PAHO and the WHO, the LFA has a special agreement with the Faculty of Medicine at the UMSA, for provide the UV data needed by the epidemiological studies and by the postgraduate school on Public Health.

On the technical side, the LFA has several agreements with a lot of international partners. The first of them was with the Brazilian INPE which allows the LFA to run the Brewer station at La Paz. This collaboration includes the LFA as a member of the South American Network for Ozone layer Monitoring, with station deployed in Brazil, Bolivia, Chile and Antarctica. The collaboration includes not only the exchange of data but also training and joint research.

The LFA started a expansion of the number of Bolivian sites for UVR monitoring, and next September, we will be installing a station in the city of Tarjia, in agreement with the local university (Universidad Autonoma Juan Misael Saracho). It is foreseen a future expansion towards the cities of Cochambamba and Santa Cruz for the next year, depending on the funding side.

Related to the radiation aspects (including the UV bands) the LFA has an agreement with the Meteorological Institute of the University of Munich, Germany on both the theory of the radiative process and the measurements, linked also with the diurnal circulation on the Altiplano.

With the Space Physics Laboratory (SPL) at the Vikram Sarabhai Space Centre (VSCC) of the Indian Space Research Organization (INSO) is an agreement for the monitoring of the atmospheric aerosols and its relation on the radiative transfer properties. This includes studies on the near-UV band and the tropospheric ozone, linked to the generation of urban smog.

With the European Space Agency (ESA) the LFA has an agreement to carry out research on the vertical distribution of aerosols, including stratospheric clouds. For this, the ESA gave the LFA an alexandrite LIDAR which will be starting operations very soon, we estimate at mid-September.
FUTURE PLANS

The LFA had presented a proposal for research to the WHO, one project for a network of UV-monitoring stations distributed among localities in Peru and Bolivia; a second project for a system devoted to ensure the quality of the sun glasses commercialized in the Andean countries; and a third project aimed to refine the Parrish classification of skin types covering the range of the Native American people, specially for the inhabitants of the Andean region. The projects were accepted by the PAHO/WHO Office at La Paz, and redirected to PAHO’s central office in Washington, later the documents should be transferred to the WHO’s Headquarters.

Besides the route taken by the aforementioned projects, the LFA is opening a new station for solar UVR in the city of Tarija, in the Southern part of Bolivia. Due the recent natural gas boom in the region, there is a lot migration towards the city of Tarija and its surroundings, and as it can be considered also as “high altitude city” (2700 m asl) we considered worthy to start measurements there.

Another project in the planning stage is a new “Technical Cooperation among Countries” (TCC), sponsored by the PAHO, this time would be between Bolivia and Ecuador. This TCC is some like the second chapter of the previous TCC between Peru and Bolivia, where the LFA “exported” the know-how of the UVI campaigns.

The ESA´s alexandrite LIDAR will be operating since next September, and we hope to get the first validated results on clouds and tropopause height for the end of the year.

In addition, the LFA is now engaging itself in the development of some small, portable and cheap system for working as dosimeters. These equipments can be based on diodes acting as sensors, or based on the fluorescence of some special materials. This research is at its first stage, just started few months ago.

NEEDS AND RECOMMENDATIONS

Among the several needs of the LFA is the lack of some equipment, as a set of standard UV lamps for calibration, or spectrometers, one for working at the LFA, and other portables, for a better monitoring during the field campaigns. Maybe the most useful equipment for the LFA activities at the moment will be a Microtops (Solar Light Co.) to be used both at fixed locations or during the field campaigns.

On a different side, we need to carry out some atmospheric sounding, in order to get a real temperature profile over our station at La Paz. The profile will be used both for refining the Umhker measurements and the LIDAR data retrieve.

REFERENCES


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BRAZIL

OBSERVATIONAL ACTIVITIES

The Ozone Laboratory of the National Institute for Space Research (INPE), was created in 1985 and the coordinator is Dr Voker W.J.H.Kirchhoff. In the present it is formed by 4 Ph.D.s, 2 engineers, 5 technicians and a few graduate students in special MSc and PhD programmes. Our major activity is to make observations of the ozone layer using a network of ground based spectrophotometers, of the Dobson and the Brewer types. We presently operate 2 Dobson stations and 6 Brewer observation sites: Natal and Cachoeira Paulista are Dobson sites; Natal, Cuiabá (now, São José dos Campos), Cachoeira Paulista, Santa Maria (1992 to 2002), La Paz, and Punta Arenas (1991 to 2000) are Brewer sites. In addition, ozone concentrations are also measured by the ECC sounding technique on balloons. A long term measurement programme at Natal has been operational since 1978. Special field campaigns have also been made at other sites, especially in Amazonia, to study biomass burning effects. More recently, instruments to measure the UV-B radiation have been added to the network.

<table>
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<tr>
<th>SITE</th>
<th>LAT. (SOUTH)</th>
<th>LONG. (WEST)</th>
<th>DOBSON NUMBER</th>
<th>GUV NUMBER</th>
<th>BREWER NUMBER</th>
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<td>2005-2005</td>
</tr>
</tbody>
</table>

Calibration activities

Five Brewer spectrophotometers were calibrated by International Ozone Services Inc. (IOS) in 2004: São José dos Campos (B#056), Cachoeira Paulista (B#124), Cuiabá (B#081), La Paz (B#110) and Natal (B#073).

The Ozone Laboratory participated in international calibration in 1994, in Spain, where the Natal Dobson (093) was shipped with our expert. In 1997 expert Bob Evans, from NOAA, checked the Natal Dobson, on a visit to Natal, but did no adjustments; the Buenos Aires WMO Intercomparison, in December 2001 and 2003, has shown that the Natal Dobson (093) did not need any corrections, even doing some work on it, such as electronic repairs/improvements, optics cleaning, and wedge calibrations. The C.Paulista Dobson (114) and a correction was adjusted in 5%.
Three GUV was calibrated in 2001, in Sao Jose dos Campos, Brazil, using standard instrument of Biospherical Instruments Inc.. The GUV 9285, is operating in Natal, the GUV 9255, in Cachoeira Paulista and the GUV 9285, in Brazilian Antarctic Station.

RESULTS FROM OBSERVATIONS AND ANALYSIS

Total column ozone observations

**Brewer and Dobson spectrophotometers**

Ground based total column ozone has been measured continuously at low latitude sites, using Brewer spectrophotometers. In addition, two of these sites also operate Dobson spectrophotometers to obtain total ozone. The tropical Brewer-Dobson sites are Natal (6° S, 35° W) and Cachoeira Paulista (23° S, 38° W). The new Brewer spectrophotometer ozone data set for Natal and Cachoeira Paulista is presented it is compared with the TOMS version 8 (V8), from 1997 to 2005 (June). Only direct sun measurements have been used in this analysis.

![Figure 1](image1.png)

**Figure 1:** The figure shows a new 8 years data set of the Brewer, obtained at Natal (a). The data are presented as running means of 31 days and this data varies between minima of 250 and 290 DU, and shows large year to year variability. The fig.1b shows the difference parameter Brewer – Toms (version 8).

![Figure 2](image2.png)

**Figure 2:** The figure shows a new 8 years data set of the Brewer, obtained at Cachoeira Paulista (a). The data are presented as running means of 31 days and this data varies between minima of 250 and 290 DU, and shows large year to year variability. The fig.2b shows the difference parameter Brewer – Toms (version 8).
The figure shows a new 26 years data set of the Dobson, obtained at Natal (a) and C.Paulista (b). The data are presented as mensal average (black line) and running means of 15 days (grey line) and this data varies between minima of 240 and 300 DU, and shows large year to year variability. The average is 266.5 DU and the standard deviation is 10.5 at Natal and 269.3 DU at Cachoeira Paulista and the standard deviation is 12.9.

The Tables 2 and 3 give further statistical details of the data sets. The total column ozone data are compared with the Total Ozone Mapping Spectrometer, Toms data, versions 7 and 8. The data set of 6 years (1997 – 2003) is discussed.

<table>
<thead>
<tr>
<th>STATION NAME</th>
<th>INSTR. AVERAGE</th>
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<th>MAX.</th>
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<tr>
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<td>12.3</td>
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A new set of ground based total column ozone data is described for the period 1996 to 2004 (May) at the high altitude (3,400 m) site La Paz (16.5° S, 68° W). This station operates a Brewer spectrophotometer. These are compared with the Total Ozone Mapping Spectrometer, Toms, satellite data (version 8).

Table 3. Monthly Averages of the difference parameters: data statistics for 100*(BRW-DOB)/BRW, 100*(BRW-TMS)/BRW and 100*(DOB-TMS)/DOB, in %.

<table>
<thead>
<tr>
<th>STATION NAME</th>
<th>DIFFER. AVERAGE</th>
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<th>MAX.</th>
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<td>-18.1</td>
<td>12.6</td>
<td>74</td>
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A new set of ground based total column ozone data is described for the period 1996 to 2004 (May) at the high altitude (3,400 m) site La Paz (16.5° S, 68° W). This station operates a Brewer spectrophotometer. These are compared with the Total Ozone Mapping Spectrometer, Toms, satellite data (version 8).
Figure 4: Shows a new 8 years data set of the Brewer, obtained at La Paz. The data are presented as running means of 31 days and this data varies between minima of 235 and 270 DU. The average and the standard deviation are 252.1 ± 9.4 DU (a). The fig. 4b shows the difference parameter Brewer – Toms, version 8. The average difference is slightly negative before 2000 and close to zero after that, with higher deviations.

Ozonesondes

Since 1978, weekly ozonesondes were launched in Natal, Brazil, and campaigns were made in Punta Arenas, Chile< (1995, 1997 and 2001), in La Paz, Bolivia (2000) and Brazilian Antarctic Station (1992, 1999, 2003 and 2004).

Figure 5: Average ozone profile characterizing the normal profile of ozone concentration, expressed as partial pressure, at Natal, Brazil, Punta Arenas, Chile and compared with ozone profile at Ascension Island. (F. Guarniere, Ph.D. Thesis, INPE 2001).

Results are described from an intense field campaign, at the Brazilian Antarctic Station Comandante Ferraz, on King George Island (62.1° S; 58.4° W) during the Spring of 2003. Ozone was measured using a ground based Brewer spectrophotometer, filter photometers, and the vertical profile was obtained on several days using balloon-borne ECC ozonesondes. In terms of the UV-B index, higher values were seen during 2003: on two occasions the Index passed the level of 9; which is larger than values observed on any previous campaign at the site.
Figure 6: Shows the comparison between the UV-B index (a) and total ozone (b) for September and October, 2001 and 2003. Higher values were seen during 2003 when the ozone hole appeared earlier and the minimum of ozone was present during several consecutive days. The anti correlation for ozone and UVB (%) during the spring of 2003 (c).

Figure 7: shows a composite of the vertical profile of the severe ozone hole of October 6, plus a "normal" profile shown for comparison, obtained on October 20. The second panel shows the ozone integrals measured by a Brewer spectrophotometer, plus the ozone integrals from vertical soundings, shown with x sign. The UV-B index observed on this day was 9.9 and the ozone was 121 DU measured with the Brewer spectrophotometer.

DISSEMINATION OF RESULTS

Data Reporting

The Brewer data have been submitted for the WOUDC, since 2004 and the Dobson data since 1978.

Information to the public

The UV forecasts is in web site www.dge.inpe.br/ozonio

Relevant scientific papers


PROJECTS AND COLLABORATION

Project in the Brazilian Antarctic Programme : The ozone and UVB radiation over Brazilian Antarctic Station and Punta Arenas, Chile.

Collaboration with the project SHADOZ (Southern Hemisphere Additional Ozonesondes).

Collaboration with the San Andres University, La Paz, Bolivia

Collaboration with the Magallanes University, Punta Arenas, Chile

FUTURE PLANS

Participation in the Internacional Polar Year (YPI) and International Heliophysical Year (IHY).

NEEDS AND RECOMMENDATIONS

It is very important the support for the annual calibrations and maintenance of the Brewer.

Financial support for trips techniques and participation in Ozone and UV Meetings, Congresses and Symposium.

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BULGARIA

OBSERVATIONAL ACTIVITIES

One of the goals, outlined in the Recommendations of the last meeting of the Ozone Research Managers is the systematic measurements, which provide the basis for understanding the ozone regime, its trends and validation the effects of the measures requested by the Montreal Protocol.

Column measurements of ozone and other gases/variables relevant to ozone loss.

In Bulgaria, the first total ozone measurements were initiated to the early 1960s, under the supervision of Prof. Dr R. D. Bojkov. Germany carried them out using Dobson spectrophotometer # 64 provided for about 5 years. After a few years interruption Russian filter ozonometers started to be used in the Bulgarian National Institute of Meteorology and Hydrology. In 1998 with the financial support from WMO two Russians ozonometers M-124 were renovated and calibrated at Main Geophysical Observatory – St. Petersburg. The measurements at only one station (NIMH-Sofia) could be maintain (but experiencing technical problems because of the device age).

Profile measurements of ozone and other gases/variables relevant to ozone loss

In the period 1983-1992, balloon ozone soundings were released once a week at the NIMH-Sofia. For that purpose were used ozonesondes OSE – manufactured in the former German Democratic Republic. The activities were interrupted largely due to financial difficulties resulting from transition to market economy. From May-2001 a Vaisala DigiCORA III—a PC based radiosounding system for measuring pressure, temperature and humidity has replaced the Russian radiosounding system. The present financial status doesn’t allow us to expand the measurements of the ozone vertical profiles with the above-mentioned Vaisala system, because of the expensive additional equipment (ozone sensors, special balloons, etc.).

UV measurements

At the present moment we are not provide a modern spectral UV-radiation monitoring. Such kind of regular measurements are very desirable to be developed in our country, but again there is a shortage of funds.

Note: The NIMH experiences financial difficulties to buy modern equipment for measuring Ozone, ozone profiles, UV solar radiation, NOx profiles.

RESULTS FROM OBSERVATIONS AND ANALYSIS

The comparison between the monthly variations of the total ozone over Sofia for 2003 and 2004 is presented at the next Figure 1.

The monthly variations of the total ozone over Sofia for 2004, compared with those ones over Potsdam and Rome are presented at the further Figure 2.

All data are being sent every month to the WMO World Ozone and UV Data Center operated by the Canadian AES in Toronto.
A comparison for the monthly mean magnitudes of the total ozone over Sofia for 2003 and 2004

Figure 1

A comparison for the monthly mean magnitudes of the total ozone for Rome, Potsdam and Sofia for 2004 year

Figure 2
Surface ozone

Another important topic is the surface ozone. Initial investigations of the surface ozone in Bulgaria began ten years ago. The following goals were pursued: to evaluate the surface ozone state in Sofia; to ascertain the diurnal and seasonal ozone variations; to investigate ozone behaviour with respect to meteorological conditions.

Site description. The measurements were performed in Sofia, located in the western part of Bulgaria (42° 49' N, 23° 23' E, 530 m. a.s.l.). The observation site is about 7 km to southeast of Sofia center and possesses a ground cover of fairly well vegetation. At 100 m distance from the site the road of considerable car traffic runs. The ozone recorder was installed at height of about 10 m above the ground level.

Instrument. The ozone detector used in the investigations is chemiluminescent analyzer, model 3-02P1, OPTEC Inc. The measuring principle of the sensor is arisen in ozone presence chemiluminescence of an organic dye, adsorbed on the solid state composition. The ozone analyzer has the following characteristics: response time is no more than 1 s, the sensitivity is 2 µg/m3. Periodically, the analyzer was calibrated by using an external O3 generator. The measurements were performed mostly at the daylight hours and less regularly in twenty-four hour period. The analysis of the diurnal ozone variations is carried out by using the hourly values of the ozone concentrations determined as 15-min average.

Diurnal variations. The pattern of diurnal variations of the surface ozone concentrations is strongly influenced by meteorological conditions. The pronounced O3 maximum in the daytime, which is explained in terms of vertical mixing process and photochemical ozone production, occurred on clear windless afternoons.

The ozone data show a maximum in summer months, roughly three-four times higher that in winter months. During the fine windy weather the dilution of the atmospheric pollutants takes place. So the decreased ozone concentrations are detected and ozone level is approximately constant throughout the day. However, in the cases when vertical exchange is limited (autumn-winter period, nocturnal inversions) the wind enhances the vertical mixing and increases the ozone content near the ground. The cloudiness strongly decreases the ozone concentrations near the ground but when it is foggy the ozone content is very low, often zero.

So, the ozone concentrations sensitively reflect meteorological conditions at which measurements are performed. It is very like that more realistic information about temporal and spatial ozone variations may be obtained if ozone data received at similar meteorological situations are analyzed. The surface ozone behavior clearly shows a seasonal variation with a summer maximum.

The variations are indicated by monthly mean, obtained by averaging clear and overcastted days mean concentrations. The minimal, 20-35 µg/m3 ozone concentrations were detected during winter period, the maximal, 60-100 µg/m3 ozone content near the ground was observed in summer months.

Only in windless days diurnal cycle of ozone concentrations displays pronounced maximum in the early afternoon (12:00-14:00 Local Time). The forcing of the wind with increased speed and the cloudiness decreases ozone pollution. Average summertime daylight means at site vary from 100 to 50 µg/m3, depending on meteorological circumstances.

The peak concentrations during photochemical episodes rarely exceeded 130 µg/m3 and are observed a several times during summer season.
It is considered that episodes with high surface ozone concentrations in southern Europe show local character and are associated with local primary pollutant emissions, but in western Europe summer smog is due to long-range transport of ozone and its precursors and so has transboundary character.

**Summary:** The experimental data from Sofia site and from other sites of Balkan peninsula (with the exception of Athens), for which information is available show that summer ozone concentrations (peak and average) have more lower values in comparison with those, measured in western and central Europe.

In general, the ozone pollution doesn’t exceed the EU threshold values. The result is consistent with the model calculations, which show that in spite of the efficiency of the photochemical ozone production (the number O₃ molecules per NOₓ molecule) is higher in southern Europe than in western Europe, the chemical ozone formation per unit area is more intensive in the western part of the Continent due to the high precursors concentrations.

**DISSEMINATION OF RESULTS**

**Data reporting**

All data are being sent every month to the WMO World Ozone and UV Data Center operated by the Canadian AES in Toronto.

**Information to the public** (e.g. UV forecasts)

In case of inquiry we provide roughly information on a base of distributed Large-Scale UV Index forecasts by Germany.

**Relevant scientific papers**


**PROJECTS AND COLLABORATION**

National project, Peculiarities in the ozon variations and a study of the processes which determine them. ; Project № H3 1406, 2004-2007, funded by the Bulgarian Ministry of Education and Science.
FUTURE PLANS (e.g. new stations, upcoming projects, instrument development)

NIMH would like to establish a regular station for ozone and UV solar radiation measurements. The very appropriate site is Ahtopol (42°05' 02,8" ; 27°57'08,2") . It is the former Bulgarian-Russian rocket station for middle atmosphere soundings and it is situated at the Bulgarian south Black sea coast.

NEEDS AND RECOMMENDATIONS

NIMH needs modern equipments for measuring total ozone and ozone profile, UV solar radiation, NOx profiles.

AN OFFER: The Bulgarian NIMH proposes, the former Bulgarian-Russian rocket station for middle atmosphere soundings at Ahtopol (42°05' 02,8" ; 27°57'08,2") , for a place of a permanent international site for measuring total ozone and ozone profile, UV solar radiation, NOx profiles, etc. Please, the interested potential participants to sent a letter of intent to the Bulgarian NIMH.

****
OBSERVATIONAL ACTIVITIES

The Meteorological Service of Canada (MSC), part of Environment Canada, is the Canadian government department responsible for atmospheric ozone research. Its column ozone and UV monitoring programme is based on Brewer spectrophotometer measurements made at nine sites. Ozonesondes are flown at least weekly from six of these sites and from four new, recently established stations. Column abundances of other molecules important to understanding ozone chemistry and climate change are measured by Fourier Transform Spectroscopy (FTS) at two locations. The World Ozone and UltraViolet radiation Data Centre is operated by the MSC on behalf of the World Meteorological Organization WMO.

Although intense resource pressures and a protracted re-organization are taking place within Environment Canada, the MSC continues to support an extensive range of activities in the fields of ozone and ultraviolet radiation research and monitoring.

Column Measurements of Ozone and Other Gases

Brewer spectrophotometers are currently being operated at 9 stations in Canada (Saturna Island, British Columbia; Stoney Plain, Alberta; Bratt’s Lake, Saskatchewan; Churchill, Manitoba; Resolute Bay, North West Territories; Alert and Eureka, Nunavut; Toronto, Ontario; Goose Bay, Labrador). This reflects the closing of three relatively recently established observing sites (Winnipeg, Manitoba; Montreal, Quebec; and Halifax, Nova Scotia) as a result of resource pressures. The instruments are programmed to make total ozone measurements on the sun, moon and zenith sky. Near-real time total ozone data is used with the Canadian Weather Prediction model to generate public forecasts of the UV-index; real time UV scan data are used for public information and validation of the UV forecasts. The raw data from the Brewers are processed in the Brewer Data Management Centre, which is also used to process data from several Brewer instruments operated in other countries. The Canadian sonde data as well as ozone and UV data from the Brewers are archived and made available to all users through the World Ozone and UV Radiation Data Centre (WOUDC).

Profile Measurements of Ozone

Ozonesondes are flown at 6 of the column ozone measuring stations (Stoney Plain, Churchill, Resolute Bay, Alert, Eureka, and Goose Bay, Labrador) and at four new stations (Kelowna, British Columbia; Bratt’s Lake, Saskatchewan; Egbert, Ontario; Yarmouth, Nova Scotia) where the primary goal is the measurement of ozone in the troposphere. The Brewer Spectrophotometers also make Umkehr measurements of the vertical profile of ozone.

UV Measurements

Broadband measurements

Narrowband filter instruments

Environment Canada does not support these measurement types.

Spectroradiometers

The Brewer Spectrophotometers at all Canadian column ozone stations also make spectral scans of the horizontal UV irradiance. The data are reported in the WOUDC data base. Some stations are now equipped with double monochromator versions of the Brewer (Mark III). The instruments are re-calibrated on a two-year refurbishment and re-calibration cycle and an active life
cycle management programme is underway to replace the present network instruments with MK III Brewers at the rate of one per year

**Calibration Activities**

Toronto is the WMO/GAW Brewer Spectrophotometer Ozone Calibration Centre. The ozone calibration reference is a group of three single monochromator Brewers, the Brewer 'Triad', that are characterized regularly and taken approximately every two years to a high altitude, low-latitude station (Mauna Loa) in order to track their extraterrestrial readings; except for these trips they remain in Toronto. Figure 1 demonstrates that the Triad is maintaining a long-term reference accuracy better than 1 %. Most field Brewer calibrations are done on site by bringing another Brewer (a 'Travelling Standard') to the station and making simultaneous measurements there. The Travelling Standard will normally be one of three instruments that are compared at least twice per year against the reference Triad in Toronto. Besides maintaining the reference and travelling instruments and a Dobson spectrophotometer, the Calibration Centre continues work on ozone metrology such as the relationships between ozone measurements made at different wavelengths and with different viewing geometries from the ground or space and the effects of temperature on ozone measurements. A double as well as a single Brewer are operated permanently by the MSC at the NDSC Mauna Loa station for research purposes as well as to provide a comparison for instruments being transported to Mauna Loa for absolute calibration.

MSC participated in the first use of the European Brewer Reference Standard from Izana, Spain in September, 2005. The new reference which consists of a Triad of double monochromator Brewers maintained at Izana, Tenerife in the Canary Islands will provide a redundant, independent reference for Brewer calibration in Europe. It is intended that the Toronto Triad and the Izana Triad will be maintained in agreement to high precision through comparisons like the one held in Mazagon, Spain in September.

**RESULTS FROM OBSERVATIONS AND ANALYSIS**

The MSC operates the WOUDC on behalf of the WMO. The availability of all types of data from the WOUDC and their value depends to a considerable extent on the prompt submission of data from those agencies throughout the world that make ozone and UV measurements. Generally the submission of data is highly satisfactory. There are minor exceptions such as the lack of some ozonesonde data sets and spectral...
UV data from some countries in Europe. However, the current volume of spectrally-resolved UV data in the WOUDC is approximately 400 station-years, which may be more than 75% of what could be made available. Figures 2 through 5 indicate the kinds of data and numbers of stations reporting to the WOUDC. During the past six years the WOUDC has moved towards making products that assist the originators and users of UV and ozone data with quality control. The centre now accepts ozone and UV data in near real time and posts current maps of column ozone obtained from current ground-based and satellite instruments. Daily hemispheric and global maps (Figures 6 and 7) are available for all periods during the past forty years. Also various forecasts maps of ozone (at present KNMI, NCEP and MSC) are posted on the site. Data from the new OMI satellite instrument will soon be included to replace the now unreliable EP-TOMS data. The Centre is still struggling to increase the amount of ‘raw’ Brewer data (so-called B-files) that are submitted.

Analyses from the data centre are contributed to the Ozone Assessment process and for the preparation of the WMO OzoneBulletins.

**THEORY, MODELLING, AND OTHER RESEARCH**

The Canadian Middle Atmosphere Model (CMAM), collaboratively developed over the last decade by scientists from Canadian universities and Environment Canada, is a middle atmospheric climate general circulation model (GCM) stretching from the ground to ~95 km, or ~0.001 hPa. This model incorporates complex, online gas-phase and heterogeneous chemistry for the middle atmosphere. The CMAM was involved in the last WMO intercomparison aimed at assessing current middle atmospheric GCMs capabilities for describing the current and future states of the stratosphere and the impact of greenhouse gases and chlorine loading upon the ozone layer in particular. A new WMO scenario experiment is currently underway involving similar work with newer model versions intended to continue this task. The currently running simulation using CMAM covers 1960-2050+ as part of the latest SPARC/WMO assessment.

Stratospheric chemistry has also been coupled to a version of the Canadian Global Environmental Multiscale Model (GEM) for weather forecasting extended to 0.1 hPa. This has been done for the ESA-funded project ‘Coupled Chemical-Dynamical Data Assimilation’. This project, led by Environment Canada in collaboration with The Belgian Institute for Space Aeronomy (BIRA) and York University, is a study of ozone chemistry, dynamics, and their interactions in a data assimilation context.

Both of these models, CMAM and GEM, are being employed in data assimilation mode using the Environment Canada 3-D variational system (3DVar). 3DVar has been adapted to allow the assimilation of species observations. To support this, the preparation of a database of ozone-related observations from various sources has been undertaken. Short-term preliminary assimilations of ozone observations have been performed using data from the OSIRIS, SBUV/2, TOMS, and GOME-2 instruments.
The Canadian Space Agency and Environment Canada are supporting the CMAM Facility for Data Assimilation and Modelling (CMAM-FDAM). Its principal objective is to provide support to the Canadian atmospheric measurement community. In that context, species products relying on assimilated dynamics are being provided for sites and periods of interest. This is to eventually incorporate products from species assimilation.

**Figure 6:** Total ozone map from the WOUDC for February 23, 2005 showing low ozone off the coast of Greenland.

**Figure 7:** The same data as in Figure expressed as a departure from historically normal levels. Note that depletions reached more than 40%.

### DISSEMINATION OF RESULTS

#### Data Reporting

Canadian column ozone measurements, ultraviolet radiation measurements and ozonesonde profiles are all submitted to the WOUDC on a regular basis by the MSC.

#### Information to the Public

Canada developed a UV Index in April, 1992. Since then Canadian public weather forecasts and reports have included the UV Index. Surveys indicate that there is a widespread public awareness of the Index and the data suggest that the majority of the public have modified their behaviour in response to the information provided. Six years ago MSC and Health Canada cooperated to develop a special programme to educate school children about UV exposure. It is called the “Children’s UV-Index Sun Awareness Programme” and was initially directed toward primary school children but now includes high school students as well. Part of the programme is World Wide Web (WWW) based and involves the students making and reporting measurements.

Addresses:

- World Ozone and UV Data Centre: [http://www.woudc.org/](http://www.woudc.org/)
Information on the state of the ozone layer is released on the WWW each week. It includes a comparison of the current two-week average ozone values over Canadian stations with estimates of un-depleted ozone data based on an analysis of historical records.

Ozone maps that are prepared for scientific use as indicated in Section 2, are also freely available to the general public on the WWW (Figures 6 and 7). Figures 8 and 9 compare satellite based estimated of UV irradiance to Brewer network measurements.

![Figure 8: Map of mean noon (11 am-1 pm) UV index values for July estimated from TOMS.](image1)

![Figure 9: The same as Figure 8 but estimated from Brewer measurements.](image2)

**PROJECTS AND COLLABORATION**

**WMO/GAW Biennial Brewer Users’ Workshops**

Canada supports the Global Ozone Observing System through organizing and Chairing the Brewer Users’ Workshops. These are held in different host countries every two years and are intended to improve the consistency and quality of ozone observations through the sharing of knowledge concerning the operation and maintenance of the Brewer instrument. They also provide a mechanism for the propagation of scientific information to encourage a wider range of measurements to be made and to provide feedback on a scientific level to improve operations. Canada hosted the Seventh Brewer users’ meeting in Toronto in September, 2002. The most recent meeting was hosted by the Brewer Spectrophotometer’s manufacturer, Kipp & Zonen B.V., in Delft, the Netherlands, in June, 2005. Between 4 and 6 MSC staff organize and participate in these meetings.

![Figure 10: The PEARL observatory. The Eureka research facility is undergoing a full-scale upgrade, including the installation of a 128 kbs satellite communications link.](image3)
Arctic Ozone Research

The Arctic Stratospheric Ozone Observatory (ASTRO) at Eureka, Nunavut (80°N) was established in 1992 as a contribution from Canada to the WMO/GAW Network for the Detection of Stratospheric Change (NDSC). The observatory instrument complement included Raman (added in 1996) and Rayleigh lidars for the measurement of ozone, water vapour, density and aerosols; FTIR spectrometers both for atmospheric thermal emission and for solar and lunar occultation; and various UV/Vis spectrometers, including modified Brewer spectrometers. However, since the 2002 Ozone Assessment, which led policy-makers to the conclusion that the ozone depletion issue was solved based on the observed decline in regulated, ozone-depleting chemicals, resourcing of the stratospheric science programme has decreased significantly, resulting in the Eureka observatory being at first moth-balled and then ceded to the university community in 2004.

In 2005, the university consortium - the Canadian Network for the Detection of Atmospheric Change (CANDAC) - was successful in gaining 5-year funding to re-establish an atmospheric research facility at Eureka. The new laboratory is called the Polar Environment Atmospheric Research Laboratory (PEARL) and is operated by that consortium. It includes partners from a number of Canadian Universities and from other countries. Within Canada it is supported by funding from nine different federal and provincial organizations. The major contributors are: the Canadian Foundation for Innovation (CFI), the Canadian Foundation for Climate and Atmospheric Science (CFCAS) and the Natural Sciences and Engineering Research Council (NSERC). There are also contributions in kind from the MSC. It is hoped that some research involvement from the MSC can be maintained.
The overall objective of the new PEARL laboratory encompasses air quality, climate change and ozone studies. The laboratory will be fully functional by 2007 in time to participate in the International Polar Year (IPY). The instrumentation of the former laboratory has been maintained and upgraded to enable the continuation of previous datasets and new observations are planned for the study of radiation, clouds and aerosols in the lower atmosphere, and composition and waves in the upper atmosphere.

The OSIRIS instrument team is led by a principal investigator from the University of Saskatchewan in Saskatoon. OSIRIS was launched in March, 2001 on the Swedish satellite ODIN in an international collaboration that also involves French researchers. The OSIRIS spectrometer has been producing limb radiance spectra since it was commissioned in August, 2001. Ozone and NO2 vertical profiles are available from these measurements. These have exceptionally high vertical and spatial resolution. The Canadian Space Agency renewed funding for the OSIRIS project in the spring of 2005, so data will continue to be available for at least two more years.

The Atmospheric Chemistry Experiment (ACE) satellite, also called SCISAT, to make atmospheric measurements relevant to ozone depletion, primarily focussed on the Arctic wintertime and early springtime stratosphere. This satellite mission is based on a proposal submitted by a mission scientist from the University of Waterloo. SCISAT was launched on August 12, 2003 and is currently making valuable occultation measurements with an infrared Fourier transform spectrometer (FTIR) and an MSC-developed diode-array spectrometer operating in the UV/visible/NIR wavelength range. The data will provide concentration profiles of more than ten trace gases as well as information about the
characteristics and occurrence of polar stratospheric clouds. The science team of ACE reflects substantial collaboration with teams in Belgium, France and the USA.

![Figure 15: The mean of 29 ozone profiles taken with ACE-FTS (Green) and MAESTRO (Blue). The 'error bars' indicate the standard deviation of the 29 profiles. (Courtesy of J. Kar, U. Toronto).](image)

**TOMS3F**

MSC participated in a NASA-led project in spring, 2001 to improve our understanding of the relationship between satellite-based (TOMS) measurements of ozone and measurements made by ground-based instruments at high latitudes. The TOMS3F campaign provided measurements from the Fairbanks Dobson instrument, one double monochromator Brewer owned by NASA/Goddard, and one single and one double Brewer provided and operated by MSC as well as ozonesonde and Microtops data. The data have not yet been published, but preliminary assessment has indicated that the agreement between double Brewer instruments and TOMS observations is very good while systematic errors in Dobson and single Brewer measurements contribute a significant discrepancy in comparison with the satellite results. MSC is attempting to arrange participation in a follow-on campaign in Sodankyla, Finland in the Winter of 2005 - 2006.

**Brewer Spectrophotometer Manufacture and Maintenance**

After a period of uncertainty, that the supply of Brewers for the global ozone observing network has been assured by the demonstrated, continuing interest of Kipp & Zonen, B.V. of Delft, the Netherlands, the Brewer manufacturer, and the signing of a multi-year license agreement between Environment Canada and Kipp & Zonen. Maintenance and calibration services for the Brewers is also available, with both the manufacturer and International Ozone Services of Toronto supporting instruments in service at Brewer observing locations around the world. Environment Canada is actively participating in this process through the Brewer workshops as well as by providing consulting services and calibration support to both companies.
FUTURE PLANS

MSC is continuing, within resource constraints, to work on improving the basic scientific foundation for spectroscopic measurements of ozone and solar radiation. The scope of this work ranges from technical issues related to instrument performance as well as scientific studies related to optimizing the analysis of data collected in the Brewer observing network. The development of new instruments with superior performance for atmospheric remote sounding is also being addressed. For example, the MAESTRO spectrophotometer on SCISAT was developed and the flight model constructed at the MSC. MSC is attempting to arrange participation in a TOMS3F follow-on campaign in Sodankyla, Finland in the Winter of 2005 - 2006.

NEEDS AND RECOMMENDATIONS

(a) It is imperative to improve the ground-based network to a capability of detecting a 1% per decade trend in the ozone recovery rate so that a turnaround comprising a recovery in the ozone layer may be detected in less than several decades. With the failure of the TOMS instrument and its replacement by new systems such as OMI, a high quality surface network is crucial to maintain a consistency of observations both between satellites and over the life-time of an individual instrument. The development and maintenance of such a crucial network cannot be accomplished with the reduction in resources being experienced by many of the meteorological agencies within the WMO.

(b) Those responsible for decisions concerning the implementation of the Montreal Protocol and Vienna Convention on Ozone Depleting Substances within national governments must be made aware of the need for long-term consistent high-quality observations. The present belief among many policy analysts is that network observations can be easily reconfigured as a short-term cost-saving measure. They must be convinced of the importance of long-term monitoring of atmospheric trends and the enormous damage inflicted in the determination of such trends when observing sites are decommissioned.
Heads of meteorological agencies within the WMO should be apprized of the potential of assimilating ozone observations, made both from the surface and from space, as a means of significantly improving weather and air quality forecasts.

Relevant Scientific Papers

Papers published in 2002-2005:


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CHILE

INTRODUCTION

Chile is located on the extreme southwestern coast of South America. Several different scientific groups and institutions are engaged in the investigation of ozone depletion and ultraviolet radiation. The majority are studying changes in incident UV using several types of instruments, mostly broad band.

OBSERVATIONAL ACTIVITIES

Column measurements of ozone

<table>
<thead>
<tr>
<th>Instruments</th>
<th>Institution</th>
<th>Station</th>
<th>LAT. LONG.</th>
<th>Period of observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brewer MKIV</td>
<td>University of Magallanes</td>
<td>Punta Arenas</td>
<td>53S;70.9W</td>
<td>1992-2000</td>
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<td>Brewer MKIII</td>
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<td>Punta Arenas</td>
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<td>2002 - today</td>
</tr>
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</table>

Profile measurements of ozone

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<td>Punta Arenas</td>
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<td>2002 - today</td>
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<td>Ozone sondes</td>
<td>University of Magallanes</td>
<td>Punta Arenas</td>
<td>53S;70.9W</td>
<td>Campaigns spring time 1995-1996-1997-2001-2005</td>
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<td>Ozone sondes</td>
<td>DMC</td>
<td>Isla de Páscua</td>
<td>27S;109W</td>
<td>1996</td>
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</tbody>
</table>

DMC: Dirección Meteorológica de Chile (National Meteorological Service)
UV measurements

Broadband measurements

*Instruments of the groups of research.*

<table>
<thead>
<tr>
<th>Instruments</th>
<th>Institution</th>
<th>Station</th>
<th>LAT. LONG.</th>
<th>Period of observations</th>
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<tr>
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<td>Santiago</td>
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<td>1999 - today</td>
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<tr>
<td>Solar Light 501</td>
<td>University Federico Santa Maria</td>
<td>Valparaiso</td>
<td>33S;70.9</td>
<td></td>
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<tr>
<td>Solar Light 501</td>
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<td>Puerto Natales</td>
<td>51S;72W</td>
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<tr>
<td>Solar Light 501</td>
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<td>Punta Arenas</td>
<td>53S;71W</td>
<td>1997 - today</td>
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<tr>
<td>Solar Light 501</td>
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<td>Puerto Porvenir</td>
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<td>Solar Light 501</td>
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<td>Bernardo O’Higgins</td>
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*Network of DMC.*

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<th>Station</th>
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<th>Period of observations</th>
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<tr>
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<td>DMC</td>
<td>Iquique</td>
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<td>Pyranometer UVA-B</td>
<td>DMC</td>
<td>La Serena</td>
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<td>El Tololo</td>
<td>30S;70W</td>
<td>1997 - today</td>
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<td>Solar Light 501</td>
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<td>Valparaiso</td>
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<td>Concepción</td>
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<td>SUV 100</td>
<td>DMC</td>
<td>Valdivia</td>
<td>39S;73W</td>
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<td>Pyranometer UVA-B</td>
<td>DMC</td>
<td>Punta Arenas</td>
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<td>2001 - today</td>
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<td>Pyranometer UVA-B</td>
<td>DMC</td>
<td>Base Presidente Eduardo Frei</td>
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### Narrowband filter instruments

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<td>Santiago</td>
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<td>1995 - today</td>
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<td>NILU UV</td>
<td>University Magallanes</td>
<td>Base Prof. Julio Escudero</td>
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<td>2005 -</td>
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### Spectroradiometers

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<td>Brewer MKIII 180</td>
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<td>Punta Arenas</td>
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### O$_3$ Surface

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<td>Cerro Tololo</td>
<td>30S; 70W</td>
<td>1995 - today</td>
</tr>
</tbody>
</table>

### Calibration activities

The instruments of the DMC are compared and calibrated at least every two years in Valdivia. GUV 511 instruments are calibrated annually with a standard instrument sent from the factory and are part of the project Latin American, “Enhanced ultraviolet-B radiation in natural ecosystems as an added perturbation due to ozone depletion”. This project is directed by Maria Vernet (Scripps Institution of Oceanography, La Jolla, California) and financed by the Inter American Institute for Global Research, (IAI), this project concluded in 2004, is possible that a new project will be approved during 2005 and starting in 2006.

Both the Brewer and the SUV spectroradiometers possess self calibration mechanisms which are constantly checked and updated by the respective scientific group. Additionally, the Brewer is calibrated monthly with an external lamps to verify the stability of the measurements. The last calibration of the Brewer No.180 from the factory was in December, 2004. The instruments Solar Light of the group of the University of Magallanes are calibrated once per year with the instrument Brewer.

### RESULTS FROM OBSERVATIONS AND ANALYSIS

#### Some Results of Studies at Punta Arenas Chile (Lat. 53S, Long. 70W)

The Brewer instrument No. 068 was operational at Punta Arenas from May 1992 until November 2000 thanks to a cooperative agreement between INPE,Brazil (Brazilian National
Institute for Space Research) and UMAG, Chile (University of Magallanes), a new Brewer (No. 180) was bought by the Magallanes Regional Government and was installed in 2002. The Figure 1 shows the variation of the ozone column measured by Brewer from 1992 until 2005 (June). Part [a] refers to the daily averages (solid line refers to the running average, n=30).

![Figure 1: Daily and monthly mean values of total column ozone over Punta Arenas Chile 1992-2000 obtained with Brewer spectroradiometer (No 068 and No. 180).](image)

The number of days in which the AOH has been over the Magallanes region varies from year to year. Figure 2 shows the number of events of low ozone to Punta Arenas. The criteria for defining an event of low ozone is that ozone column (daily average) must be lower than the reference (mean monthly climatological values for Punta Arenas from TOMS overpass data for the period 1978-1987), minus twice the standard deviation of the mean (mean monthly - 2\(\sigma\)). The number of days per year is shown in part (a), after 1995 the higher frequency occurred in February of 1998 with 27 days. In the period of 1994-1999 there were many days of low ozone events during summer time. Between 2001 and 2003 there were fewer significant days showing a possible recuperation of the ozone over Punta Arenas. However, during 2004 the days began to increase again. From there we ask the question: Which is the situation of the recovery (if it exists) of the layer of ozone at mid latitudes. The answer to this question must wait some years until much more data is collected.
DISSEMINATION OF RESULTS

Data reporting
- GUV-Network: The database of the GUV instruments are stored and maintained by each group, also exists an archive of all data (IAI) from all stations.
- The UV-B data from DMC network and vertical profile from Isla de Pascua are being regularly sent to the World Ozone Data Centre, Canada.
- The data from Brewer 180 in the course of this year will be sent to the WOUDC.

Information to the public
- The National Meteorological Service gives UV-Index forecast for all the stations shown in 2.3.1.
- Since the summer of 1999 the Ozone Laboratory and RUV of the University of Magallanes provides a UV index daily forecast during spring and summer time.

Relevant scientific papers


FUTURE PLANS
NEEDS AND RECOMMENDATIONS

We would like to carry out the following activities but funds are needed.

- Construct a network of instruments to measure ozone and ultraviolet radiation along the total length of Chile using the country’s unique geographical features and scientific installations, with two or three additional Brewer Spectoradiometers in the northern and central regions.
- Implement a long term programme of continuous balloon sonde measurements to establish a profile of stratospheric ozone concentrations over Punta Arenas.
- It is imperative to implement a plan of calibration of instruments.

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CZECH REPUBLIC

INTRODUCTION

In the Czech Republic (CR) monitoring and research of ozone and UV-B solar radiation are mostly carried out in the Czech Hydrometeorological Institute (CHMI). Scientific activities are performed also by the Institute of Atmospheric Physics of the Czech Academy of Science and by the Department of Meteorology of the Charles University in Prague. While the monitoring is fully funded by the CHMI the research projects are supported also by grant agencies or by EC programmes. In recent years the extensive assistance has been provided by CHMI experts to the ozone part of the Global Atmosphere Watch Programme (GAW) of WMO.

OBSERVATIONAL ACTIVITIES

Column measurements of ozone

Daily observations of total ozone (DS and ZS) have been performed with the Dobson and Brewer spectrophotometers collocated at the Solar and Ozone Observatory of CHMI in Hradec Kralove (SOOHK) since 1962 and 1994, respectively. The observations are stored in the ozone database of CHMI and submitted to partner institutions. Both total ozone data series have been re-evaluated and re-deposited into WOUDC in 2005 [1], [2].

Profile measurements of ozone

Balloon-borne ECC ozone sondes are launched three times per a week in January - April at the Aerological Observatory (AOPH) of CHMI in Prague. The vertical profiles of ozone are stored in the ozone database of CHMI, WOUDC and NDSC, as well.

UV measurements

Broadband measurements

The broad-band UV Solar Light-Biometers are operated at three CHMI stations (Hradec Kralove, Kosetice and Labska Bouda) that are located in typical climate and geographical regions of CR (lowlands, rural land and mountains). The observations are used for the UV public information system and for research activities - see next parts of this Report.

Narrowband filter instruments

No narrowband UV radiometers are currently operated in CR.

Spectroradiometers

Spectral measurements of UV-B solar radiation (298-325 nm) and calculation of erythemal DUV irradiances have been performed with the single (MKIV) and double (MKIII) Brewer spectrophotometers at SOO-HK since 1994 and 2004, respectively. The observations are accompanied by measurements of other auxiliary radiation fluxes (global, diffuse, reflected).

Calibration activities

The above mentioned instruments are regularly calibrated towards egional or world standards of the GAW calibration centres (RDCC-E, Hohenpeissenberg, MSC/IOS Brewer Triad) and they are operated according to SOPs defined in GAW manuals. Therefore the data sets are consistent with observations from other GAW stations and they are given in relevant world calibration scales.
RESULTS FROM OBSERVATIONS AND ANALYSIS

The observations taken at SOO-HK have been used for data quality assessment, estimation of long-term ozone trends and analyses of relation between ozone and UV in the territory of CR in several recent and current international research projects joined by Czech teams - see the paragraph 5. Attention is paid mainly to investigation of relation between simultaneous Dobson and Brewer total ozone observations and between ground and the latest satellite data sets (TOMS-8, GOME/WFDOAS). The results show significant seasonal variations of differences that exceed 1% calibration accuracy of the spectrophotometers and thus they could influence the estimation of ozone trends if combined or non-homogenized data series are used - see Figures 1, 2 and [2], [3]. The quality assessment of UV spectral measurements taken with Brewers confirmed that the UV scans need to be filtered and correct (e.g. for spikes spikes) before they are deposited into data bases and used for statistical analyses.

THEORY, MODELLING, AND OTHER RESEARCH

Neural technologies have been used to simulate long-term ozone and UV changes by specialists from CHMI. The chemically induced part of the decadal ozone change was estimated by the neural model that was developed within the project CANDIDOZ and run with ERA-40, solar flux, circulation indices and AOD proxies in the European region [4]. The results showed that the magnitude of the chemical component of ozone losses has been increasing since the early sixties in the region but it depends on the latitude - see Fig. 3. While in the southern part (45° N) of the region its influence is almost negligible in high latitudes (over 50° N) the ozone losses have
reached 30-40 DU (8-12%) during last four decades. Similar neural model has been developed to simulate UV spectral irradiances and UV erythemal doses by total ozone, clearness indices and AOD at Hradec Kralove. The model is now tested by re-evaluated total ozone data series from SOO-HK and it is to be used for estimation of the UV climatology in the territory of CR during last five decades - see the project COST-726

![5-Years Mean of Estimated Chemical Factor + 95% Confidence Interval](image.png)

**Figure 3:** Time evolution of the estimated chemical component of decadal total ozone change in the European region - simulation with the neural model of CHMI, EC project CANDIDOZ [5].

**DISSEMINATION OF RESULTS**

**Data reporting**

All ozone observation taken in CR are regularly submitted into the WOUDC, Toronto and also to other partner institutions and projects - e.g. the Ozone Mapping Centre of MSC, NDSC data base, GAW cooperating stations in Central Europe, MATCH campaigns and satellite validating teams. UV observations that have been carried out under projects funded by EC (COST-713, COST-726, SUVDAMA, EDUCE, SCOUT) are reported to the European UV data base maintained by FMI.

**Information to the public**

A public ozone and UV information system has been implemented and operated by CHMI since 1999. Reports on actual and forecasted UV Indices and variation of ozone are issued for the territory of CR and disseminated to mass media daily. The system is supported by information campaigns that are also joined by medical experts [5]. The internet component of the system that is linked with international centres (e.g. TEMIS/KNMI the Netherlands and ECUVF/DWD, Germany) is located at the address: [http://www.chmi.cz/meteo/ozon/hk-e.html](http://www.chmi.cz/meteo/ozon/hk-e.html).

**Relevant scientific papers**


PROJECTS AND COLLABORATION

The Czech scientific community is involved in several research and development projects that are focused mainly on analyses of ozone and UV observations taken by national monitoring facilities and their relations to external data sets. Attention is also paid to modeling of UV radiation with the aim to the ozone change and regime of cloudiness. The long-term cooperation is pursued between CHMI and the GAW Programme of WMO. Following are the chief ongoing collaborations and projects that should be mentioned.

CANDIDOZ

“Chemical and Dynamical Influences on Decadal Ozone Change”. EC FP-5, 2002-2005. Experts from CHMI and from the Department of Atmospheric Physics of the Czech Academy of Sciences investigate:

- Differences between simultaneous total ozone data sets originated with different instruments (Dobson, Brewer, satellite - TOMS-8, GOME/WFDOAS) and their impacts on ozone trends
- Estimation of the chemical component of ozone changes in the European region using neural-models and ERA-40 proxies.
- Relation between occurrence of ozone laminae and trends in ozone profiles in NH mid latitudes.

SCOUT-O3

“Stratospheric-Climate Links with Emphasis on the UTLS”. EC FP-6, 2004-2009. The CHMI specialists are involved in its UV part. High-quality UV spectral and broadband measurements taken at Czech stations are provided to SCOUT partners. Development and tests of a CHMI’s neural UV model and its application on reconstruction of the UV climatology in CR are the goals of the Czech team. The activities follow up the previous participation of CHMI in the project EDUCE.

COST-726

“Long term changes and climatology of UV radiation over Europe”. The EC coordinated, 2004-2008. Definition of the climatology of UV radiation and selected biologically effective UV radiation doses in the territory of CR by UV models are the chief tasks of the Czech scientists in the project. The models will be tested and applied to derive UV radiation data for long time period and places without UV measurements.

GAW Ozone

For a decade experts of CHMI contribute to maintenance of the GAW ozone monitoring network. The activities are focused mainly on implementation of new technologies and calibration of instruments at stations in developing countries (Capacity Building) and on cooperation with GAW central facilities. The following missions and achievements have been realized in the recent years.
Technical service on ozone spectrophotometers (WMO IC in Dahab, Egypt, 2004)
Re-installation and upgrade (semi-automation) of ozone spectrophotometers at GAW stations (Botswana, Egypt, Kenya, South Africa in 2004/2005)
Training of operators from ozone stations - annual campaigns (15 trainees in 2003-2005)
Assistance in realization of calibration campaigns of the Regional Dobson Calibration Centre - Europe, Hohenpeissenberg, Germany
Assistance in establishment of the Regional Brewer Calibration Centre - Europe, Izana, Spain
Maintenance of the Dobson Web
Site: http://www.chmi.cz/meteo/ozon/dobsonweb/welcome.htm
Donation of the software packages for Dobson and Brewer data management at GAW stations
Participation in GAW scientific groups (SAG-Ozone, Dobson and Brewer Committees)

Currently the above activities are mostly sponsored by the Czech governmental project: “Maintenance of the Network for Monitoring the Ozone Layer in Developing Countries” established by the Ministry for Environment of CR for the period 2004-2006.

FUTURE PLANS

The long-term monitoring of ozone and UVB radiation will be pursued in CR as specified above. Attention will be paid mainly to maintenance of calibration condition of the instruments and to implementation of updated SOPs, so that observations from the Czech facilities keep the highest achievable quality. Further establishment of new stations is not planned.

Participation in the ongoing projects mentioned in this Report will continue. Future activities will be focused on the Czech contribution to building up the IGACO system in the regional scale. This includes the assistance to the Regional Dobson and Brewer Calibration Centres and on testing new technologies for Brewer spectrophotometers, above all.

The UV simulation model developed at SOO-HK will allow CHMI experts to reconstruct the UV climatology of the last 5-6 decades. The results are expected to be applied in Czech and international integrated environmental projects.

NEEDS AND RECOMMENDATIONS

Quality of assimilated ozone observations from the integrated ozone monitoring system should generally reach the calibration accuracy of the ground system so that recovery of the ozone layer is reliably identified and documented in the future.
Accuracy of ground and satellite ozone observations in high latitudes needs to be better understood and improved through analyses of available records or by experimental missions.
Analyses and modeling of the Arctic ozone losses and their relation to the stratospheric dynamics should get the highest priority in research projects in order to estimate a possible influence of the climate change on the state of the ozone layer.
The WMO/GAW Programme and the UNEP should continue their key role in the capacity building and in the international coordination of ozone monitoring and research.
Sustainable quality of UV spectral measurements in the global network requires establishment of global/regional references and implementation of standard calibration procedures for particular types of UV radiometers.
DENMARK

Stratospheric ozone monitoring

Daily observations of total ozone are performed by the Danish Meteorological Institute (DMI) in Denmark and Greenland:

<table>
<thead>
<tr>
<th>Station</th>
<th>Location</th>
<th>Instrument</th>
<th>Start of observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copenhagen</td>
<td>56°N, 12°E</td>
<td>Brewer Mark IV</td>
<td>May 1992</td>
</tr>
<tr>
<td>Sondre Stromfjord</td>
<td>67°N, 51°W</td>
<td>Brewer Mark II</td>
<td>September 1990</td>
</tr>
<tr>
<td>(Kangerlussuaq)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thule Air Base</td>
<td>77°, 69°W</td>
<td>SAOZ UV-vis 1024 diode array</td>
<td>September 1990</td>
</tr>
<tr>
<td>(Pituffik)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

On non-regular basis, total ozone has also been measured from Qaanaaq in Greenland (78°N, 69°W), using the DMI Dobson #92 instrument since early 2000. One reason for moving the instrument to this location is the possibility to measure total ozone in the polar night in winter time using the Moon as the light source.

Weekly ozone soundings have been performed using balloon-borne ECC sensors from Scoresbysund (Illoqqortoormiut, 71°N, 22°W) since January 1993. Additional ozone soundings have also been performed on campaign basis from Scoresbysund and Thule each winter since January 1992 and occasionally from Copenhagen. Many of these ozone soundings have been used in European Match-campaigns to assess the chemical ozone depletion in recent Arctic winter/spring seasons.

The measurements are reported to databases under Network for the Detection of Stratospheric Change (NDSC) and World Ozone and UV-radiation Data Center under the WMO-programme Global Atmosphere Watch.

Thule and Sondre Stromfjord are primary Arctic stations within the Network for the Detection of Stratospheric Change (NDSC). Scoresbysund is a complementary NDSC-station. In addition to the DMI-instrumentation, aerosol lidars are operated at Thule and Sondre Stromfjord by the University of Rome (Italy) and SRI International (USA), respectively, together with an FTIR spectrometer at Thule, operated by National Center for Atmospheric Research (USA). A long series of balloon-borne backscatter soundings of polar stratospheric clouds (PSCs) and aerosol have been performed from Thule, Sondre Stromfjord, and Scoresbusund by DMI in collaboration with the University of Wyoming (USA). DMI also collaborates with Service d’Aéronomie du CNRS (France) for daily total ozone measurements by a SAOZ UV-vis spectrometer at Scoresbysund.

Ozone research

DMI has participated in all major European/US Arctic ozone research campaigns since the beginning the 1990’es such as EASOE, SESAME, THESEO, THESEO-2000/SOLVE and VINTERSOL. DMI has also participated in the HIBISCUS campaign from Bauru, Brazil, in February 2004, investigating cirrus formation and transport of water vapour in the tropical tropopause. In addition, DMI has participated in numerous past and ongoing research project, funded by the European Commission and Danish research agencies. DMI currently participates in the integrated EU-projects “Stratosphere-Climate links with emphasis on the UTLS” (SCOUT-O3), “Quantifying the climate impact of global and European transport systems” (Quantify), and “Global Earth-System monitoring using satellite and in-situ data” (GMES-GEMS). DMI will be CO-PI together with the Alfred Wegener Institute (Germany) in coordinating bi-polar stratospheric ozone and UV research in connection with the International Polar Year 2007-2008 (IPY).
The ozone research at DMI relates to:

- Transport studies of stratospheric ozone, including dilution effects at mid-latitudes from Arctic ozone depletion. In this research domain filling trajectory calculations, based on meteorological analyses from the European Centre for Medium-Range Weather Forecasts (ECMWF), are applied together with available observations of total ozone and ozone profiles. This modelling concept is expanded to include microphysical and chemical modules.
- DMI has also been involved in studies of the accuracy of stratospheric temperatures in ECMWF and other analyses products, used for stratospheric research.
- Studies of polar stratospheric clouds (PSCs) by microphysical simulations and balloon-borne experiments from Greenland and Northern Scandinavia. For several years, the DMI has been collaborating with the University of Wyoming on balloon-borne backscatter soundings of stratospheric aerosols and PSCs from Greenland. This collaboration has been extended into a European/US collaboration on balloon-borne in-situ measurements of chemical and physical properties of PSC particles, performed from Northern Scandinavia.
- Microphysical modelling of cirrus clouds, including the formation of sub-visible cirrus in the tropics of relevance for transport of water vapour to the stratosphere.
- Studies of the effects of aircraft on cirrus formation and their radiative properties in the upper troposphere.
- Climate modelling, relating to the influence of ozone on the stratospheric circulation and climate. DMI operates climate models which include the effects of changes in stratospheric ozone.
- The DMI participates in several scientific and validation studies to utilise date from ESA’s Envisat and other satellites, both on ozone, other trace gases, and aerosol measurements.
- Ozone and UV trend assessments. The DMI has contributed to the latest WMO/UNEP and European assessments on stratospheric ozone and to the Arctic Climate Impact Assessment Report and have taken part in the review process of assessment reports. DMI is currently involved in preparing a SPARC-assessment report on PSCs.

**Ultraviolet radiation**

Daily measurements of the surface UV-B radiation are performed by DMI at Thule, using a high resolution spectroradiometer, since summer 1994. The instrument has been intercompared to a NIWA instrument to become NDSC classified.

The DMI participates in EUMETSAT’s Satellite Application Facility on Ozone Monitoring, aiming at the development of operational UV-index products, based on satellite measurements of the ozone layer.

UV-B index forecasts, based on Danish total ozone measurements, were initiated at DMI in summer 1992. This public service runs every summer season, made public on the Internet and in several media.

**Further information**

Further information on the stratospheric ozone research and monitoring at DMI, including publication lists and lists of past and ongoing research projects can be obtained on the Internet at [http://www.dmi.dk/eng/index/research_and_development/the_division_fo.htm](http://www.dmi.dk/eng/index/research_and_development/the_division_fo.htm)

General information about DMI can be obtained at [www.dmi.dk](http://www.dmi.dk)

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EGYPT

OBSERVATIONAL ACTIVITIES

Column measurements of ozone

At Egypt, only Egyptian Meteorological Authority (EMA) is responsible for measurements of column ozone amount and operates the main total ozone-monitoring network. Long-term daily observations of total ozone have been performed at the regional ozone center of EMA at Cairo (30.08°N, 31.28°E) with the Dobson Spectrophotometer (D096) since 1967. Since 1984 second Dobson instrument (D069) has been maintained at Aswan (23.97°N, 32.87°E) to measure the amount of ozone over tropical area. At the late of 1998 Brewer Spectrophotometer mark II (B143) has been maintained at Matrouh (31.33°N, 27.22°E) to measure the total ozone and SO2 over northwest coast area of Egypt. With the end of 1999 third Dobson Spectrophotometer (D059) has been maintained at Hurghada (27.28°N, 33.75°E) to measure the amount of ozone over Red sea area.

Vertical distribution of ozone

Vertical distribution of ozone in the atmosphere is measured with Dobson and Brewer Spectrophotometers (Umkehr method) at Aswan, Matrouh and Hurghada. The N-values are stored in the ozone database at EMA and they are also deposited in the WOUDC, Toronto.

Surface ozone

EMA measure surface ozone outside urban regions, at Hurghada (27.28°N, 33.75°E) which is an official WMO Global Atmospheric Watch (GAW) station. Also EMA measure surface ozone at Sidi Branni (31.37°N, 25.53°E). South Valley University (SVU) in cooperation EMA has been measured surface ozone at Qena (26.20°N, 32.75°E).

UV measurements

Broadband measurements

EMA take the measurements of broadband UV solar radiation using Eppley Ultraviolet Radiometer at Cairo and Aswan since 1989. Also EMA in cooperation with SVU have been measured the broadband UV radiation at Qena since 2000.

Narrowband filter instruments

EMA measured the biologically effective solar UV-B radiation by UVB-1 Pyranometer at Cairo, Aswan since 1998 and at Rafaah (31.22°N, 34.20°E) since 2000. The measurements of the global UV-B are performed with the Brewer single monochromator for different solar zenith angles at Matrouh. Also EMA in cooperation with SVU have been measured the UV-B radiation at Qena since 2000.

The present network of measurements of ozone and UV radiation at Egypt are shown in Table (1).
Table (1): Operational network of ozone and UV radiation at Egypt.

<table>
<thead>
<tr>
<th>Type of observation</th>
<th>Location</th>
<th>Org.</th>
<th>Instrument</th>
<th>Start</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Ozone Column</td>
<td>Cairo</td>
<td>EMA</td>
<td>Dobson No. 096</td>
<td>1967</td>
</tr>
<tr>
<td></td>
<td>Aswan</td>
<td>EMA</td>
<td>Dobson No. 069</td>
<td>1984</td>
</tr>
<tr>
<td></td>
<td>Matrouh</td>
<td>EMA</td>
<td>Brewer No. 143</td>
<td>1998</td>
</tr>
<tr>
<td></td>
<td>Hurghada</td>
<td>EMA</td>
<td>Dobson No. 059</td>
<td>2000</td>
</tr>
<tr>
<td>Ozone Vertical Profile</td>
<td>Aswan</td>
<td>EMA</td>
<td>Dobson No. 069</td>
<td>1984</td>
</tr>
<tr>
<td>(Umkehr)</td>
<td>Matrouh</td>
<td>EMA</td>
<td>Brewer No. 143</td>
<td>1998</td>
</tr>
<tr>
<td></td>
<td>Hurghada</td>
<td>EMA</td>
<td>Dobson No. 059</td>
<td>2000</td>
</tr>
<tr>
<td>UV Radiation</td>
<td>Cairo</td>
<td>EMA</td>
<td>Eppley Radiometer</td>
<td>1989</td>
</tr>
<tr>
<td></td>
<td>Aswan</td>
<td>EMA</td>
<td>Eppley Radiometer</td>
<td>1989</td>
</tr>
<tr>
<td></td>
<td>Qena</td>
<td>SVU</td>
<td>Eppley Radiometer</td>
<td>2000</td>
</tr>
<tr>
<td>UV-B Radiation</td>
<td>Matrouh</td>
<td>EMA</td>
<td>UVB-1 Pyranometer</td>
<td>1998</td>
</tr>
<tr>
<td></td>
<td>Rafaah</td>
<td>EMA</td>
<td>UVB-1 Pyranometer</td>
<td>2000</td>
</tr>
<tr>
<td></td>
<td>Qena</td>
<td>SVU</td>
<td>UVB-1 Pyranometer</td>
<td>2000</td>
</tr>
</tbody>
</table>

Calibration activities

Calibration of instruments

All Dobson instruments are regularly calibrated every 4 years towards world standard. EMA ozone scientists taking into consideration the maintenance and calibration of the Dobson instruments regularly.

The WMO and EMA in close cooperation and assistance of the USA National Oceanic and Atmospheric Administration’s Climate Monitoring and Diagnostics Laboratory (NOAA/CMDL) organized the International comparison of Dobson Spectrophotometers at Dahab, Egypt 23 February – 12 March, 2004. Further assistance was provided by the German Weather Service’s European Dobson Regional Calibration Center (DWD-RDCC/E) and by the Czech Hydro-meteorological Institute’s Solar and Ozone Observatory (SOO-HK). It was a campaign to maintain the network of Dobson ozone spectrophotometers operated in the Africa region (R1). Comparison Dobson spectrophotometers from Algeria (D011), Botswana (D015), Kenya (D018), Seychelles (D057), Egypt (D096, D069, D059), South Africa (D089) and Nigeria (Shimatzu 5703) towards the World Secondary Dobson Standard Instrument (WSSI) No. 65 from NOAA/CMDL’s World Dobson Calibration Center (WDCC) Boulder, Co, USA, to determine the existing calibration level. European Regional Standard (D064) also participated for calibration verification. Sixteen specialists from five countries and the WMO Secretariat participated at the Intercomparison. This action is a fulfillment of WMO/GAW/QC requirements for monitoring of atmospheric total ozone.

Training of the Brewer operators

EMA in co-operation with WMO carries out a training programme for operators of ozone Arab countries. At 2004 EMA trained three operators from El Emirate country for installation, calibration and operation of Brewer spectrophotometer.

RESULTS FROM OBSERVATIONS AND ANALYSIS

Variation and Trend of ozone

EMA studied the trend of ozone at Cairo, Aswan, Matrouh and Hurghada for different periods, shown in table (2). The highest values of negative trend were found through the period from January 1990 to December 1995 over Egyptian ozone stations especial over Cairo. While the highest values of positive trend was found after 1999. Figure (1) represents the monthly variation
and trend of ozone at Cairo from October 1967 to December 2004 while Figure (2) represents the monthly variation and trend of ozone at Aswan from December 1984 to December 2004.

Table (2): Ozone trend at Egyptian ozone stations for different periods.

<table>
<thead>
<tr>
<th>Period of Trend</th>
<th>Cairo</th>
<th>Aswan</th>
<th>Matrouh</th>
<th>Hurghada</th>
</tr>
</thead>
<tbody>
<tr>
<td>01/1970 – 12/1980</td>
<td>0.0859</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>01/1985 – 12/1990</td>
<td>0.0372</td>
<td>0.1343</td>
<td></td>
<td></td>
</tr>
<tr>
<td>01/1985 – 12/1995</td>
<td>-0.0274</td>
<td>-0.0174</td>
<td></td>
<td></td>
</tr>
<tr>
<td>01/1990 – 12/1995</td>
<td>-0.2201</td>
<td>-0.1273</td>
<td></td>
<td></td>
</tr>
<tr>
<td>01/1990 – 12/2000</td>
<td>-0.0434</td>
<td>-0.0246</td>
<td></td>
<td></td>
</tr>
<tr>
<td>01/1995 – 12/2000</td>
<td>-0.0006</td>
<td>0.092</td>
<td></td>
<td></td>
</tr>
<tr>
<td>01/1999 – 12/2004</td>
<td>0.1216</td>
<td>0.1211</td>
<td>0.5844</td>
<td></td>
</tr>
<tr>
<td>Beginning – 12/2004</td>
<td>0.0009</td>
<td>0.0066</td>
<td>0.6354</td>
<td>0.0301</td>
</tr>
</tbody>
</table>

Figure (1): Monthly variation and trend of ozone at Cairo from Oct. 1967 to Dec. 2004.

Figure (2): Monthly variation and trend of ozone at Aswan from Dec. 1984 to Dec. 2004.
Variation and Trend of ozone and UVB at Matrouh:

Figure (3) represent the monthly variations and trends of Ozone and UVB at Matrouh from November 1998 to December 2004. The Ozone amounts take the maximum value at spring while the UVB radiation takes the maximum value at summer. From the end of 1999 the trend of ozone amount increased while the trend of UVB radiation decreased.

\[ y(\text{UV}) = -6.3032x + 3082.5 \]
\[ y(\text{O3}) = 0.5844x + 296.82 \]

\[ \text{Joule/m}^2 \]

\[ \text{DU} \]

\[ 0 \quad 1000 \quad 2000 \quad 3000 \quad 4000 \quad 5000 \quad 6000 \quad 7000 \]

\[ 0 \quad 200 \quad 220 \quad 240 \quad 260 \quad 280 \quad 300 \quad 320 \quad 340 \quad 360 \quad 380 \quad 400 \]

\[ \text{MONTH} \]


\[ \text{UV-B} \quad \text{OZONE} \quad \text{UVB Trend} \quad \text{O3 Trend} \]

Figure (3): Monthly variations and trends of Ozone and UVB at Matrouh from 01/1999-12/2004.

THEORY, MODELLING AND OTHER RESEARCH

EMA study the analysis and forecast of UVB radiation over 4-sites at Egypt and compare with Erythemal of UVB measured by TOMS.

DISSEMINATION OF RESULTS

Data reporting

The ozone data collected from the network of Egyptian ozone stations by EMA at Cairo regional ozone center monthly. Data files of ozone are transmitted regularly with SO\textsubscript{2} to World Ozone Data Center (WOUDC) in Toronto, Canada.

Egyptian Environmental Agency Affairs (EEAA) monitoring Ozone Depleting Substances (ODS’s) as CFCs, Halons, CC14, C2H3CL3, HCFCs, HBFCs, CH2BrCl and CH3Br. EEAA sent the annual data of ODS’s to Ozone Secretariat of UNEP, Kenya and Multilateral Fund (MLF), Canada.

Information to the public

Matrouh lie on the coast of NW Egypt and summer resort. The scans are used for calculation of actual values of UV Index (UVI) daily presented for the public during the seasons especially the summer season. UVI is a numerical risk scale and a way of describing the daily danger from solar UVB radiation. The EPA used the following classification of the UV exposure level based on the UV index (0-2 minimal, 3-4 low, 5-6 moderate, 7-9 high and >10 very high).UVB insulation displays a daytime variation with maximum at solar noon, figure (4) and variation with months take a maximum at summer months (figure 5c). UVB protection is critical during summer and especially so in the hours around solar noon. A person being out in the sun during midday hours more than ten minutes if you are without protection.
Figure (4): Diurnal variation of DUV and UVI on a clear summer day over Matrouh.

(a) Winter

(b) Spring

(c) Summer

(d) Autumn

Figure (5): Diurnal variation of UV index over Matrouh at different seasons.

Relevant scientific papers

Through the last three years Scientists at EMA carry out a large number of papers have been published in various journals. Most recent ones are:


Sharobiem, W.M. and F.M. El-Hussainy: Sulfur dioxide observations and trends over Egypt. 7th Workshop on meteorological and sustainable development, 10-13 March 2002, Cairo, Egypt.


Sharobiem, W.M.: Stratospheric ozone variations and trends over Egypt. 28th International conference for statistic computer science and its applications, 12-17 April 2003, Cairo, Egypt.
PROJECTS AND COLLABORATION

EMA in cooperation with South Valley University (SVU) have been measured the broadband UV and UV-B radiation and other meteorological parameters.

National projects through the National Ozone Unit in EEAA to phasing out ODS’s as phase out plane of CFC’s and Methyl Bromide. Also projects of Halon Bank and Solvent project.

FUTURE PLANS

EMA co-operate with the Czech Hydro-meteorological Institute’s Solar and Ozone Observatory (SOO-HK) for develop Dobson instruments at Cairo, Aswan and Hurghada. Where the data take by Semiautomatic Dobson Data Recorder.

The WMO and EMA in close cooperation and assistance of the International Ozone Services Inc., Toronto, Canada organized the Calibration of Brewer instrument at Matrouh next October 2005.

National phase out plan in EEAA for ODS’s.

NEEDS AND RECOMMENDATIONS

- We are in great need for scientific research programme in ozone and climate change model.
- We will appreciate assistance to start measurements of vertical ozone distribution advice to elaborate a by ozonesonde especially at Aswan station (tropical area).
- We need technical and financial assistance for the regular calibration of Brewer with the traveling standard.

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ESTONIA

INTRODUCTION

In Estonia, atmospheric total ozone and UV radiation monitoring began in 1994. The monitoring is carried out at the Tartu-Tõravere Meteorological Station (58°.16'N, 26°.28'E, 70 m a.s.l.) and the research work by the Department of Atmospheric Physics of the Tartu Observatory, located at the same site. The studies of atmospheric aerosols and atmospheric transmittance are also performed at the Institute of Environmental Physics of the University of Tartu. The Tartu Observatory has participated in the European Community EDUCE research project and is also taking part in the COST 726 activities.

INSTRUMENTS AND MONITORING

The Tartu-Tõravere Meteorological Station is the successor of the Meteorological Observatory of the University of Tartu, operating regularly since 1865. The first attempts to measure solar radiation at this station were made in the 1930s. Since January 1950, regular measurements have been performed outside the town and from 1965 the station has been at the present site. In 1999, the station was included in the Baseline Surface Radiation Network (BSRN).

At present the operating UV sensors are:

- Erythemally weighted: Scintec UV-SET (since 1998)
- YES UVB-1 (since 2005)
- PMA2200 used for calibration transforms (since 2003)
- UV-B narrowband (306 nm) Kipp&Zonen CUVB1 (since 2002)
- UV-A broadband UVSB2 (since 2002)

Direct sun total ozone measurements are made using a MICROTOPS-II instrument.

At two other stations - Tallinn-Harku (59°.24'N, 24°.36'E, 39 m a.s.l.) and Tiirikoja, (58°.51'N, 26°.57'E, 32 m a.s.l.) the narrowband UV-B sensors are installed and the Pärnu station (58°.23'N, 24°.30'E, 5 m a.s.l.) has a broadband UV-A sensor.

Taking into account the previous experience of the exploitation the minispectrometers a minispectrometer AvaSpec-256 produced by Avantes company was obtained by the Tartu Observatory and is suited for the field measurements by adding necessary auxiliary equipment.

Additionally, a teflon diffuser was made and studied for cosine response. A quartz fiber of 4 m length and 100 µm diameter connects the diffuser to the spectrometer. An UFS-5 glass optical filter was installed between the diffuser and fiber to reduce the scattered light inside the spectrometer and to guarantee the reliable recording of signal in the whole measured spectral region. For reliable recording of noise signals, the optical interface is automatically covered by a shutter before and after each measurement cycle.

The control of the sensitivity for the uniform recording of spectra is realized through the change of integrating time at the interval 1 to 60 s. In this way a maximum value of the signal approximately 16,000 arbitrary units is realized in each spectrum. For reducing the noise level the spectrometer is installed in a refrigerator and kept at the temperature of +7°C. Radiometric response of the system was established using the NIST (National Institute of Standards and Technology) traceable quartz FEL lamp.

The measurement process is fully computer-aided through a Linux programme. The control computer of the spectrometer is connected to the observatory web. Using the server it is possible to access any spectrum in a user-friendly form. It is also possible to track the measurements using any computer of the local web (http://sputnik.aai.ee) and also to have access to the archive of spectra.
UV CLIMATOLOGY

The Estonian total ozone climatology, based on TOMS and other available data, was published in 2002.

The first results of the proxy-based reconstruction of the erythemally weighted UV doses back to 1967 were published in 2002. These results were for the period from vernal equinox to the autumnal equinox, constituting about 90 % of the yearly dose. The sunshine duration was used as a cloud influence related proxy.

Figure 1: Reconstructed yearly and summer half-yearly erythemal doses at Tartu.

Recently, the reconstruction of the erythemally weighted daily doses has been recalculated using the daily relative sum of broadband direct irradiance and the daily relative sum of broadband global irradiance as the cloudiness influence related proxies. The first proxy was used in the cases of significant contribution of sunshine during a day and the second on almost overcast days. The correction for deviation of total ozone from its climatic value was calculated when data were available.

It was assumed that in sunshine conditions the sum of broadband direct irradiance accounts for the deviation of atmospheric turbidity from the average. In the cold period of the year, statistical relationships were derived separately for snow and snow-free conditions.

The biases between measured and reconstructed daily doses in 52-58 % of cases around the year were within ± 10 % and in 82-84 % of cases within ± 20 %. In the summer half-year, these amounts were 58-65 % and 85-92 %, respectively. In most years the results for longer intervals did not differ significantly in case of climatic ozone and therefore no corrections were made for the daily deviations before 1979. The yearly and summer half-yearly doses (constituting on average 89 % of the yearly dose) in 1979-2004 agreed within ± 2 %, except the post volcanic years and a year of extremely fine weather (2002). The largest deviation 3.5 % was met in 2002.

In Figure 1, the yearly and summer half-yearly reconstructed doses for 1953-2004 are presented. One can see that the interval 1976-1993 regularly manifests values lower than the average. The amplitude of deviations from the average in the summer half-year is within 92-111 %. The range of variation of all proxy quantities is larger. For the sum of global irradiance, it is 89.7-114.4 %. For the sum of direct irradiance, it is 74.4-132.2 %, and for the sunshine duration 79.8-132.9 %. The spring period constitutes on average 42.9 % and the summer period 46.2 % of the
yearly dose. The darkest 102 (roughly 100) days of the winter from November 1 to February 10 when the noon solar elevation remains below 15°, make up on average only 2.7 % of the yearly erythemal dose.

**Figure 2: Reconstructed erythemal doses of 100 darkest days in winters 1953-2004.**

The year-to-year variations of the erythemal dose as well as the sums of global broadband irradiance in the scale of percentage deviation from the average values are presented in Fig. 2. The variations of erythemal dose during that interval occurred in the range ± 20 %. The minimum values were met in cloudy winters with extended snow-free episodes. Since 2000, the midwinters have been darker than the average.

**PUBLIC INFORMATION**

In the summer period, when high UV levels occur, the Estonian Institute of Meteorology and Hydrology warns people of the related risks using the radio, TV and other means of mass media. Current value of the UV Index for each minute of a day is displayed on the Tartu Observatory homepage [http://www.sputnik.aai.ee](http://www.sputnik.aai.ee)

The research results as well as the general ozone layer issues have also been introduced to the general public during the public awareness campaigns conducted in the frame of the UNEP funded Institutional Strengthening programme by the National Ozone Office (2001-2004). The presentations given by the specialists of the Tartu Observatory, the Estonian Institute of Meteorology and Hydrology and the Ozone Office in a special ozone tent lasted for approximately 40 minutes. Illustrative materials in Power Point as well as NASA images on the status of the ozone layer have been shown. During all events ozone leaflets, T-shirts and balloons were distributed among the participants and refrigerators were raffled. Although the campaigns primarily focused on raising public awareness, a positive side effect was that about 5 000 old refrigerators were collected during 3 years. For the future, the general public will continue to be informed of the UV levels and ozone issues. The Country ODS Phaseout Programme consisted of three additional projects: Recovery and Recycling (UNDP), Baltic Regional Halon Bank (UNDP) and Train the Trainers in Refrigeration (UNEP). The UN programmes gave strong momentum to ODS phaseout in Estonia and brought the country to new horizons. The results are clearly reflected in reduced usage of ozone depleting substances.
In Estonia, a biennial conference, Atmosphere*Human*UV-radiation, is also held regularly in each odd year. The results of current research are introduced and discussed.

Estonia has ratified the Vienna Convention, the Montreal Protocol and all its amendments and is following the decisions of the Parties. In addition, the EC legislation on ozone depleting substances, that goes in many areas beyond the requirements laid down in the Montreal Protocol, came in force on 1 May, 2004.

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INTRODUCTION

Stratospheric research has been coordinated at European level since the late 1980s, building on a number of trans-national collaborative initiatives and EC projects supported by the research Framework Programmes (FPs) of the European Commission. The early European stratospheric research programmes (FP1-FP3, 1982-1994), focused on the investigation of potential severe Arctic ozone losses and increased UV radiation across Europe and the populated northern mid-latitudes. Results from a series of national and international programmes including the European Arctic Stratospheric Ozone Experiment (EASOE, 1991-92) and the Second European Stratospheric Arctic and Mid-latitude Experiment (SESAME, 1994-95) concluded that the winter polar stratosphere over northern Europe was primed for severe ozone losses. Large ozone losses over the Northern Hemisphere have indeed been observed in some winters in the early 1990s. This trend has continued in the early 2000s, coincide with a steady stratospheric cooling trend and new record low temperatures.

Research priorities within the 4th Framework Programme (FP4, 1994-1998) have shifted towards improving our understanding of the processes affecting stratospheric ozone over Northern Europe. The Third European Stratospheric Experiment on Ozone (THESEO 1998-2000) was a major component of this coordinated programme. At that time research focused on the mid-latitude lower stratosphere, the interaction with other layers of the atmosphere, the Arctic vortex, the tropics and sub-tropics.

Stratospheric research carried out under FP5 (1998-2002) was building on FP4 achievements with the emphasis to understand, quantify and predict stratospheric changes. This interdisciplinary research has been implemented through individual projects organised in research clusters addressing similar topics (details below).

The ongoing 6th Framework Programme (FP6, 2002-2006) is focusing on stratospheric climate interactions and on the impact of the transport modes on the upper troposphere/lower stratosphere (UTLS). Research is organised and implemented by 2 large Integrated Projects (IPs): SCOUT-O3 (Stratosphere-Climate links with emphasis On The UTLS) and QUANTIFY (Quantifying the Climate impact of Global and European Transport Systems), respectively.

Stratospheric research at European level was effectively co-ordinated by the EU Science Panel on Atmospheric Research and the European Ozone Research Coordination Unit (EORCU). The Science Panel has provided advice to the EC regarding future direction and priorities of atmospheric research for the currently running 6th Framework Programme (2002-2006) and to establish the coming 7th Framework Programme (beyond 2006). EORCU was responsible for the co-ordination of research clusters formed in the course of the 5th Framework Programme (see Table 1). EORCU also serves as the project office/co-ordination unit of the SCOUT-O3 IP funded under the 6th Framework Programme.

Effective links are maintained with existing international observational programmes such as the Network for the Detection of Stratospheric Change (NDSC) and the Global Atmosphere Watch programme of the World Meteorological Organisation (WMO-GAW) which already provides a large degree of coordination for a large number of European groups. The International Ozone Commission and the WCRP programme Stratospheric Processes And their Role in Climate (SPARC) should also be mentioned in this context.

Overall, European research has greatly benefited from the European research programmes which has provided an effective co-ordination mechanism and has helped European scientists to make major advances to the understanding of the stratospheric ozone and UVB issue. As a result, they have significantly contributed to international assessments and research experiments carried out in support of the Montreal and Kyoto Protocols.
The scientific objectives of stratospheric research were addressed under Area 2.1.2 Stratospheric Ozone Depletion in the work programme Global Change, Climate and Biodiversity, Key Action of the EC’s Environment and Sustainable Development Programme:

2.1.2 Stratospheric ozone depletion, in support of the Montreal Protocol

The target is the quantification and prediction of ozone depletion in the stratosphere and the increase of UV-radiation levels at the Earth’s surface. This focuses on the quantification of anthropogenic and natural emissions of ozone depleting substances and their transformations; reduction of the uncertainties in stratospheric-tropospheric exchange processes and the impacts of aircraft emissions; quantification of ozone loss in the stratosphere over Europe and the linkages with the polar, tropical regions and the upper troposphere; understanding of stratospheric cooling and its links to tropospheric global warming, and better quantification of its impacts; accurate determination of the atmospheric UV radiation field and its changes in the European region.

During FP5 overall 32 research projects on stratospheric ozone and UV radiation were supported by the EC (see Table 1). They include the CRUSOE concerted actions entitled “Coordination of Research into Understanding of Stratospheric Ozone over Europe” which supports EORCU. These projects together with national activities were coordinated by the following five clusters:

1. Stratospheric ozone loss (SOLO)

The central objective was to quantify the ozone depletion in the northern and middle latitudes throughout the year. The research involved measurements made by balloons, aircraft, ground-based and satellite instruments which were used to understand the causes of chemical ozone loss under various atmospheric conditions. The analysis of THESEO data continued after contract extension. These studies helped to improve our understanding of the long term trends observed over polar and mid-latitudes.

2. Coordination of Research for the Study of Aircraft impact on the Environment (CORSAIRE)

The basic objective was to address persisting uncertainties concerning the upper tropospheric and lower stratospheric processes in the tropopause region related to aviation emissions. Research focused on the formation and evolution of contrails and particles and the ozone budget in the upper troposphere and lower stratosphere region. This work also included improved predictions and scenario calculations of aviation-induced future changes in climate. It has provided the aviation-aeronautics communities and decision-makers with options to mitigate climate impact from aircraft emissions.

3. Atmospheric UV radiation (ATUV)

The main objective was to study the evolution of the UV radiation at the earth’s surface and in the atmosphere over the last ten years. Existing databases were extended and further developed to provide additional products, such as a European UV climatology using spectral UV irradiance measurements from 26 stations in Europe including actinic flux data suitable for use by a wide user community.

4. Ozone-climate interactions (OCLI)

The core objective was to study the physical and chemical impacts on climate in the past caused by variations in stratospheric ozone and to study to what extend these variations can be explained by natural and/or anthropogenic forcing. This includes scenario calculations of future
greenhouse gas emissions and halogen concentrations in order to investigate the impact of the Montreal and Kyoto Protocols.

5. Global atmospheric observations (GATO)

The main objective was to coordinate atmospheric measurements at European level to provide data at regional and global scale for ozone and related species. GATO aimed also to help ensure that all field and satellite measurements made within the European programme are available for validation and for scientific analysis. The work in GATO involved in-situ and satellite measurements, including data from new campaigns. This research contributed significantly to international observational programmes.

The clusters have been effectively co-ordinated by EORCU and the Research Directorate General. Results have been disseminated by specially organised workshops on particular topics, through special sessions at conferences (e.g. EGS) and international meetings such as the Quadrennial Ozone Symposia and the SPARC Assemblies.

VINTERSOL campaigns

VINTERSOL (Validation of INTERnational Satellites and study of Ozone Loss) was a series of major European field campaigns addressing stratospheric ozone and the natural sources of NO$_x$. VINTERSOL (‘Winter sun’ in the Scandinavian languages) has taken place from late 2002 until early 2005. Like the previous European campaigns, VINTERSOL relied on joint support from national funding agencies and from the EC’s Environment and Sustainable Development programme.

The following VINTERSOL campaigns have been carried out:
- a small balloon campaign in the tropics in late 2002;
- intensive Arctic ozone loss studies in the 2002/03 winter/spring;
- ozone loss studies in the Antarctic winter and spring 2003; and
- balloon and aircraft studies in the tropics in early 2004
- balloon and aircraft studies in the tropics in early 2005.

Most of the research projects funded under FP5 already have or will finish by the end of 2005. Nevertheless, a number of measurement and modelling activities will run continuously yielding information on processes at longer time-scale in the stratosphere, partly supported by the FP6 IPs. For details please contact the EORCU web page http://www.ozone-sec.ch.cam.ac.uk/

Stratospheric Research under the 6th Framework Programme (2002-2006)

The scientific objectives of stratospheric research are addressed under topic I.5. Stratospheric Ozone and Climate Interactions in the Work programme of the Thematic Sub-Priority 1.1.3 Global Change and Ecosystems

1.5 Stratospheric Ozone and Climate Interactions

Research will focus on future stratospheric ozone levels affected by halogens, aerosols, water and greenhouse gas emissions and how physical, radiative and chemical changes in structure and circulation in the global stratosphere will be affected by climate change. UV radiation fluxes reaching the ground and the factors affecting their transfer in the atmosphere as well as the effects of surface pollution, aviation and natural factors on the upper troposphere and lower stratosphere will be studied in the context of ozone-climate interactions.
As a result of recent calls for proposals, 2 integrated research projects were selected focusing on ozone-climate interactions and UV radiation (SCOUT-O3), and on quantifying the impact of emissions from the transport sector on climate (QUANTIFY), respectively (see Table 2). SCOUT-O3 is a 5 years project which started May 1, 2004, supported by the EC with 15 Mill. €; QUANTIFY is a 5 years project which started March 1, 2005, supported by the EC with 8 Mill. €. Please note that the scientific ambition and financial support of these projects which adds up to 23 Mill. €, definitely exceeds that of individual FP5 research cluster.

In addition to the IPs, the Quadrennial Ozone Symposium 2004 (Kos, Greece, 1-8 June, 2004) has been supported through a Specific Support Action.

Core objectives of SCOUT-O3

The aim of this project is to study and predict the evolution of the coupled chemistry/climate system with emphasis on reliable prediction of the future evolution of the ozone layer and surface UV. Forecasts will be build on refined and improved models by exploiting existing data for model testing and validation and by provision of new data on fundamental processes. In order to meet these goals, 10 project activities have been defined:

- Determination of air residence time (with major field campaign)
- The influence of clouds on the tropical UTLS (with major field campaign)
- Understanding the stratospheric water vapour trend and its consequences
- The stratospheric aerosol layer – role of TTL and possible changes
- Past UV changes, variability and trends
- Ozone variability and past changes at mid-latitudes
- Inter-annual variability in polar processes and likely changes in a changing atmosphere
- Improved understanding of the Brewer-Dobson and general stratospheric circulation
- Stratosphere/troposphere coupling – past and future
- Predictions of ozone recovery, effect on climate change on recovery and the impact of the ozone changes on surface UV

Campaigns

- Tropical aircraft campaign scheduled for November-December 2005, Darwin, Australia
- Tropical balloon campaigns planned for 2006/2007
- Age of air measurements planned for 2006
- UV-aerosol-cloud campaign, scheduled for spring/summer 2006 in Southern Europe

Core objectives of QUANTIFY

The main goal of QUANTIFY is to quantify the climate impact of global and European transport systems for the present situation and for several scenarios of future development. The climate impact of various transport modes (land transport, shipping, and aviation) will be assessed, including those of long-lived greenhouse gases like CO₂ and N₂O, and in particular the effects of emissions of ozone precursors and particles, as well as of contrails and ship tracks.

Several transport scenarios and potential mitigation options will be assessed on a sound common basis to identify the most effective combination of short and long-term measures as input for policy- and industrial decisions. The project aims to provide such guidance by focused field measurements, exploitation of existing data, a range of numerical models, and new policy-relevant metrics of climate change. The project will focus on the following activities:

- Establishment of transport Scenarios and emission inventories
- Regional dilution and processing (with emphasis on chemical conversion of ship emissions)
- Large-scale chemistry effects (impact of transport emissions on chemical composition for past and present day conditions)
• Long-term measurements of UTLS compounds
• Aviation, shipping and clouds (generation and modification of clouds by emissions of different traffic modes, with emphasis on cirrus clouds)
• Radiative forcing and climate change (contribution from different modes of transport)
• Development of improved metrics of climate change
• Synthesis of the results

Campaigns

• CIRCLE-1 aircraft campaign planned for 2007 (Most of the modelling work carried out in QUANTIFY is based on existing data records)

The 4th (and last) call of FP6, which has been launched in July 2005 offers additional opportunities for stratospheric research. Among the priorities listed under Area 6.3.VI Operational forecasting and modelling a topic on European atmospheric observation systems (indicative budget 7 Mill. €) is included. It is designed to reinforce ground-based atmospheric measurements complementary to satellites to strengthen the European component of co-ordinated international observation networks such as NDAC. This should provide a good opportunity for the European stratospheric research community to safeguard continues long term measurements.

European Assessment

The EC has published its second assessment on European research in the stratosphere in late 2001. It took almost two years and over 100 scientists to prepare this assessment which is based on European research efforts during the last few decades and the analysis of 40 years of atmospheric data. It provides a thorough review of the progress of the European research programme on stratospheric ozone, UV radiation and aircraft impact on the atmosphere during 1996-2000, including THESEO. The results of the assessment endorse the position of the EU concerning the international agreements on ozone depletion (Montreal Protocol) and climate change (Kyoto Protocol), as well as the International Civil Aviation Organisation’s regulation of the impact of aviation emissions. The assessment concludes among others that any ozone layer recovery could only become measurable around 2010 at the earliest.

The 4th FP6 call, launched in July 2005, includes under Area IX the following topic: European assessment of the impact of transport on climate change and ozone depletion. This assessment will, six years after the 1999 IPCC Special Report “Aviation and the Global Atmosphere”, provide an up-date of this report. The assessment will focus on atmospheric loading, impacts on climate change and stratospheric ozone depletion of gases and particulates from the air- and surface transport sectors, and will provide estimates of current and future trends based on FP5 project results. In case of successful application, first results are to be expected end of 2006.

Future activities

The complexity of the atmospheric processes, the scale of the scientific problems and the potential devastating impact on humans and the ecosystems caused by climate change, stratospheric ozone depletion and UV radiation require real interdisciplinary research collaboration. This has already started under the 5th and 6th Framework Programme and most probably, will continue in the 7th Framework Programme. The Science Panel on Atmospheric Research in a recent report, entitled “Atmospheric Change and Earth Science AIRES III: Research challenges”, points to the need to consolidate and strengthen these efforts to establish a solid scientific basis for developing policy options to protect the stratospheric ozone layer and the climate system. The report has identified a number of atmospheric research priorities within Earth System Science that will be most relevant for the future implementation of the 7th Framework Programme (2007-2013). In parallel, the proposal of the European Commission for the 7th Framework Programme under priority 6. Environment (including climate change) is referencing the importance of changes in the atmospheric component of the Earth System in relation to
international commitments such as the Montreal Protocol. Therefore it is likely that stratospheric research remains a EC research priority. The 7th Framework Programme is expected to be adopted by the European Council and the European Parliament in 2006.

Table 1: Research projects and clusters in FP5.

**Stratospheric Ozone Loss (SOLO) cluster**
- **CIPA** (Comprehensive investigations of polar stratospheric aerosols)
- **THESEO 2000 – EUROSOVL**E (Improved understanding of stratospheric ozone loss by measurements and modelling contributing to THESEO and SOLVE)
- **SAMMOA** (Spring-to-Autumn Measurements and Modelling of Ozone and Active species)
- **TOPOZ III** (Towards the Prediction of Stratospheric Ozone III: The Partitioning of the NOy Components)
- **QUOBI** (Quantitative Understanding of Ozone losses by Bipolar Investigations)
- **EUPLEX** (European Polar Stratospheric Cloud and Lee Wave Experiment)

**Atmospheric UV radiation (ATUV) cluster**
- **ADMIRA** (Actinic flux determination from measurements of irradiance)
- **EDUCE** (European database for Ultraviolet Radiation Climatology and Evaluation)
- **INSPECTRO** (Influence of clouds on the spectral actinic flux in the lower troposphere)

**Ozone-Climate Interactions (OCLI) cluster**
- **SOLICE** (Solar influences on climate and the environment)
- **DETECT** (Detection of changing radiative forcing over the recent decades)
- **EUROSPICE** (European project on stratospheric processes and their impact on climate and the environment)
- **PARTS** (Particles in the upper troposphere and lower stratosphere and their role in the climate system)
- **CANDIDOZ** (Chemical and Dynamical Influences on Decadal Ozone Change)

**Global Atmospheric Observations (GATO) cluster**
- **AMIL2DA** (Advanced MIPAS-Level-2 Data Analysis)
- **GOA** (GOME Assimilated and Validated Ozone and Nitrogen Dioxide Fields for Scientific Users and for Model Validation)
- **MAPSCORE** (Mapping of Polar Stratospheric Clouds and Ozone levels relevant to the Region of Europe)
- **QUILT** (Quantification and Interpretation of Long-Term UV-Visible Observations of the Stratosphere)
- **SOGE** (System for Observation of Greenhouse Gases in Europe)

**Coordination of Research for the Study of Aircraft impact on the Environment (CORSAIRE) cluster**
- **MOZAIC-III** (Measurement of Ozone, Water vapour, Carbon monoxide and Nitrogen oxides by Airbus in-service aircraft (MOZAIC-III) - O3 and H20 budgets in the UT/LS)
- **TRADEOFF** (Aircraft emissions: Contribution of different climate components to changes in radiative forcing-tradeoff to reduce atmospheric impact)
- **INCA** (Interhemispheric differences in cirrus properties from anthropogenic emissions)
- **STACCATO** (Influence of Stratosphere-Troposphere Exchange in a Changing Climate on Atmospheric Transport and Oxidation Capacity)
UTOPIHAN-ACT (Upper tropospheric ozone: processes involving HOx and NOx. The impact of aviation and convectively transported pollutants in the tropopause region)

CARIBIC 3 (Civil aircraft for regular investigation of the atmosphere based on an instrument container)

HIBISCUS (Impact of tropical convection on the upper troposphere and lower stratosphere at global scale)

SCENIC (Scenario of aircraft emissions and impact studies on chemistry and climate)

TROCCINOX (Tropical convection, cirrus and nitrogen oxides experiment)

Concerted actions

CRUSOE (Coordination of Research into and Understanding of Stratospheric Ozone over Europe)

CRUSOE II (Coordination of Research into Understanding of Stratospheric Ozone over Europe II)

Two projects supported under Area 7.2 Development of generic Earth observation technologies in the Global Change, Climate and Biodiversity, Key Action of the EC’s Environment and Sustainable Development Programme:

RAMAS (Radiometer for Atmospheric Measurements At Summit)

UFTIR (Time series of Upper Free Troposphere observations from a European ground-based FTIR network)

**Table 2: Research projects in FP6.**

**Integrated Projects (IP)**

SCOUT-O3 (Stratosphere-Climate Links With Emphasis On The UTLS)

QUANTIFY (Quantifying the Climate impact of Global and European Transport Systems)

Specific Support Action (SSA)

QOS2004 (Quadrennial Ozone Symposium 2004)

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FIJI

Summary

Ozone monitoring in Fiji is carried out only by the University of the South Pacific (USP) in collaboration with NASA/GSFC/NOAA/CMDL mainly under the SHADOZ (Southern Hemispheric Additional Ozonesondes) programme. Using ozonesondes, total column ozone (TCO), stratospheric ozone, tropospheric ozone and surface ozone profiles and amounts are being obtained since 1997. TCO, stratospheric and tropospheric ozone have shown a seasonal trend of spring maximum and fall minimum. Stratospheric ozone in particular has shown a slight decreasing trend (about 1%) since 1997-2003. Monitoring of $^7$Be for certain time intervals has also been done to study stratosphere-to-troposphere exchange (STE) processes in the region. No proper long-term UV-B monitoring programme is in place for the country yet, though measurements using a broadband spectrophotometer have been going on for some time. Data however is also available, for about a year, from measurements done using a narrow band UVB-1 pyranometer.

Recent research at USP has focused on identifying ozone trends at a few South Pacific sites (Samoa, Tahiti and San Cristobal) including Fiji. Study has also been done to explain the trends and variations seen in ozone amounts at all levels (TCO, stratosphere, troposphere and surface) at each of these sites. Future research plans at USP mainly include setting up a proper continuous UV-B monitoring programme and improving the method of studying STE processes. A Dobson or a Brewer spectrophotometer is also planned to be introduced along with ozonesonde measurements.

INTRODUCTION

Fiji is located within the South Pacific region (18.1°S, 178.2°E). The only institution involved with scientific research and monitoring of ozone is the University of the South Pacific (USP) located in the capital city Suva in the main Island of Viti Levu. The ozone research at USP is carried out in collaboration with NASA/GSFC/NOAA/CMDL. The lead agencies at USP for this major project are the Department of Chemistry and the Pacific Centre for Environment and Sustainable Development (PACE-SD).

OBSERVATIONAL ACTIVITIES

Relevant observational activity in Fiji involves monitoring of vertical ozone profiles using electrochemical concentration cell (ECC) ozonesondes and periodic UV-B monitoring using broad and narrow band UV meters.

Profile Measurements of Ozone

Since 1997, vertical ozone profiles have been measured on a weekly basis, using a model 6A ECC ozonesondes. The vertical profile data from these measurements are being used to obtain the total column ozone and stratospheric ozone levels over Fiji since 1997.

UV-B Measurements

Currently there is no continuous UV-B monitoring programme in place for Fiji. Some measurements are being done by the Department of Physics and by the Fiji Meteorological Services using a broadband meter. However, with the absence of a proper validation method the accuracy of the data is questionable.

UV-B was continuously measured for nearly one year, from July 2003 to July 2004 by the Department of Physics using a narrow band UVB-1 pyranometer with a spectral response in the 280-320 nm range. After July 2004, no measurements were done and now the pyranometer is being moved to the Fiji Meteorological Services (Nadi) where continuous monitoring is being planned to be carried out.
Calibration Activities

Since each ozonesonde is a new instrument, pre-launch procedures are designed to ensure valid data recording is done. The ozonesonde being used is a model 6A sonde provided by NOAA and it has taken part in sonde inter-comparison experiments such as stratospheric ozone inter-comparison (STOIC) in 1989 (Komhyr et al., 1995) and Julich ozonesonde inter-comparison experiment (JOSIE) in 1996 (Smit et al., 1996).

There is currently no proper calibration method in place for any UV-B monitoring done.

RESULTS FROM OBSERVATIONS AND ANALYSIS

Stratospheric Ozone

Figure 1 shows the stratospheric ozone trend from 1997-2003 drawn from 0.25 km averaged ozone profiles. In the plot the whiskers represent the inner 90th percentile of the data, boxes the inner 50th percentile, the black bar the median, the red bar the mean and the black dots are the outliers in each (monthly) data set.

![Figure 1: Stratospheric ozone trend for Fiji during 1997-2003.](image)

The ozonesonde analysis has shown a seasonal cycle with high values during the spring months of September-November (SON) and low values during fall/winter months of May-July. The variability in ozone amounts appears to be highest during the SON months. These results are similar to those reported by Thompson et al. (2003).

Figure 2 shows the monthly averaged stratospheric ozone trend during 1997-2003. There appears to be a downward trend in stratospheric ozone over the 7-year period.

![Figure 2: Monthly mean stratospheric ozone trend for Fiji during 1997-2003.](image)
Total Column Ozone (TCO)

Figure 3 shows the TCO trend during 1997-2003 for Fiji, which reveals a seasonal trend and variability similar to that of stratospheric ozone.

Figure 3: TCO trend for Fiji during 1997-2003.

Ultraviolet-B (UV-B) Radiation

The UV-B data obtained during the one year of monitoring from 2003 to 2004 by the UVB-1 pyranometer is given in Figure 4.

Figure 4: Daily average UV-B levels at Suva, Fiji, from July 2003 to July 2004.
OTHER RESEARCH

Other research relevant to the stratospheric ozone is the studying of the stratosphere-to-troposphere exchange processes.

Stratosphere-to-troposphere Exchange (STE)

One of the ways of studying the complex process of STE events is through tracer studies using cosmogenic radionuclides such as beryllium-7 (\(^{7}\text{Be}\)) (Dibb et al., 1992). Atmospheric aerosols at USP are collected using high-volume air samplers and the activity of \(^{7}\text{Be}\) is determined using a high-resolution gamma-ray spectrometer with a hyper-pure germanium (HPGe) detector available at the Department of Physics at USP. The standard filters used for analysis are obtained from the Environmental Monitoring Laboratory (EML) in New York. Data of \(^{7}\text{Be}\) measurements are available only from September 1999 to September 2000 and for part of 2003. Correlations with tropospheric ozone (Figures 5 and 6) suggest occurrence of STE events in the region. However, in view of the limited \(^{7}\text{Be}\) data, conclusions cannot be definitive. Since \(^{7}\text{Be}\) technique is time consuming, there is a need for a better method for determining any STE events in the region. In future studies we propose to attach a frost-point hygrometer to the ozonesonde for studying the STE processes.

Figure 5: Correlation between \(^{7}\text{Be}\) and Tropospheric ozone for Fiji, 2003.
DISSEMINATION OF RESULTS

Data Reporting

The ozone profile data collected in Fiji is sent to NOAA in Boulder, Colorado. The data from there is then transferred to the SHADOZ (Southern Hemispheric Additional Ozonesondes) archives.

PROJECTS AND COLLABORATION

The major international collaboration is with NASA/GSFC/NOAA/CMDL. Under this collaborative effort ozone monitoring in Fiji began during the Pacific Exploratory Mission (PEM)-Tropics A mission of NASA in the spring of 1996. The phase B of this mission (PEM Tropics-B) was conducted in the fall of 1999. Since 1997, ozonesonde measurements are being done on a weekly basis as part of the SHADOZ (Southern Hemispheric Additional Ozonesondes) programme initiated by NASA/GSFC/ NOAA/CMDL. More information can be found in the SHADOZ web site http://croc.gsfc.nasa.gov/shadoz/.

This international collaboration was aimed at studying the atmospheric chemistry over the Pacific region (over two seasons) and to build ozone database for satellite validation, processing and modeling. Moreover, ozonesondes are currently also launched to coincide with the Aura satellite overpass.

At a national level collaborations with the ODS unit of The Department of Environment have provided a means of creating awareness of the ozone hole problems and use of ozone depleting substances such as CFCs.

Collaborations within the Departments (Chemistry, Physics and PACE-SD) of the University has also enabled completion of a number of projects especially, for Master of Science students (Chandra, 2004; Mani, 2004; Gopal, 2000). Recent research at USP has looked into:

- Comparative study of ozone trends at all levels (surface, troposphere and stratosphere) in Fiji, Samoa, Tahiti, San Cristobal (Galapagos) and the South Pole (Amundsen-Scott Station) during 1997-2003, using data collected by NOAA/CMDL.

Figure 6: Correlation between $^7$Be and Tropospheric ozone for Fiji, 1999-2000.
Identifying the relationship between tropospheric ozone variations in the South Pacific and biomass burning by using clustered and individual trajectory analysis.

Investigating vertical mixing of air by relating tropospheric ozone anomaly with surface $^7$Be levels in Fiji.

Identifying widespread regional convection (SPCZ) as one of the important sources of variability in surface and tropospheric ozone.

Investigating the influence of quasi-biennial oscillation and solar cycle on stratospheric ozone trends.

Relating surface UV-B levels with stratospheric ozone variations.

FUTURE PLANS AND RECOMMENDATIONS

The following activities are planned for the future:

- Continue monitoring vertical ozone profiles under the SHADOZ programme.
- Study the STE processes more accurately by coupling a frost-point hygrometer with the ozonesonde launches, hence monitoring vertical water vapor profile regularly.
- Start a continuous UV-B monitoring programme and study the changes in the influx of surface UV-B radiation as a result of stratospheric ozone variations. It is planned to acquire a good narrow band UV-B pyranometer for the Department of Chemistry and also have a regular standardization and validation programme. For effective study of surface influx of UV-B, the atmospheric aerosol loading and cloud cover also needs to be determined. Hence, it is also planned to introduce a light detection and ranging (lidar) instrument and develop cloud characterization capacity at the university in conjunction with the Fiji Meteorological services. Accurate measurements of surface UV-B levels will also pave the way for the currently incomplete biological studies such as UV-B induced damage to plants, marine organisms, cases of skin cancer and cataracts.
- Introduce a Dobson or a Brewer spectrophotometer to enhance the capacity of ozone monitoring and research at USP.

Being a developing Island nation, funds and expertise are not readily available in Fiji to carry out the above activities effectively. Thus, completion of the above activities will depend heavily on funding from donor organizations.

ACKNOWLEDGEMENTS

The ozone project at USP is funded by NASA/GSFC and implemented through NOAA/CMDL under the SHADOZ programme. Sincere gratitude to Bryan Johnson of CMDL for ensuring timely shipment of supplies for regular ozone monitoring.

Data from measurements made under the SHADOZ programme can also be found in Thompson et al. (2003).
References


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FINLAND

OBSERVATIONAL ACTIVITIES

Column measurements of ozone and other gases/variables relevant to ozone loss

The discovery of the Antarctic "ozone hole" in the mid 1980s initiated several ozone monitoring activities also at northern high latitudes. In Finland ozone column monitoring has been carried out by the Finnish Meteorological Institute at Sodankylä (67.4N, 26.6E) since 1988 and at Jokioinen (60.5N, 23.3E) since 1994. At both stations an automated system based on Brewer spectrophotometer is continuously operated. At Sodankylä Arctic research centre (FMI-ARC) wintertime ozone columns are also monitored with a SAOZ spectrophotometer which is operated in cooperation with CNRS-Paris already since 1990. The SAOZ measurements also provide NO₂ and OClO column amounts. This instrument works at low solar zenith angles and is thus capable of measurements during the wintertime at high latitudes. Multiyear ozone measurements from both stations have shown large inter-annual variations, in addition significant ozone loss has been observed in the Arctic stratospheric vortex during several years since early 1990s.

Profile measurements of ozone and other gases/variables relevant to ozone loss

Ozone soundings has been carried out since 1989 at Sodankylä where balloon ozone sensor measurements are carried out regularly throughout the year, while in Jokioinen these measurements are conducted during winter and spring when chemical ozone depletion is expected.

Another long-term initiative at FMI-ARC related to stratospheric ozone is the measurements of polar stratospheric cloud (PSC) properties. PSCs play an essential role in chemical chlorine activation and subsequent ozone depletion. PSCs are generally divided in two types based on their optical parameters, type II are large particles of primarily water ice, type I are typically smaller particles of nitric acid trihydrate or supercooled ternary solution droplets. At Sodankylä these stratospheric cloud particles have been observed during stratospheric campaigns since 1991/1992 by lidar and since 1994 by aerosol backscatter sondes.

At Sodankylä, since December 2002, stratospheric humidity is monitored in winter months using frost point mirror hygrometers from NOAA and/or alpha-lyman hygrometers developed at Central Aerological Observatory of RosHydromet. Already earlier, in January 1996 an Arctic dehydration event was recorded and investigated at Sodankylä using NOAA/CMDL hygrosondes. FMI has also hosted an international intercomparison campaign of lightweight hygrosondes in January-February 2004.

The national meteorological institutes in Finland (FMI) and Argentina (SMN) started a joint ozone research programme in 1987, including total ozone measurements over Marambio (64.1°S, 56.4W), Antarctica. In 1988 routine ozone soundings were started at Marambio. Recently FMI and SMN have started Aerosol optical depth and radionuclide measurements at Marambio.

UV measurements

Broadband measurements

FMI operates SL501 broadband instruments at six sites in Finland. These instruments provide on-line information on the erythemal irradiance that is published thru the internet along with the UV-Index forecast.

Narrowband filter instruments

FMI cooperates with Argentina and Spain on Antarctic ozone and UV. In 1999 the collaboration was extended to include UV radiation research. The established UV monitoring
network consists of NILU-UV instruments in Marambio, Belgrano and Ushuaia. In Sodankylä a NILU-UV radiometer has been used to measure UV radiation of a reference field within a large field experiment of FUVIRC (Finnish Ultraviolet International Research Center).

**Spectroradiometers**

FMI has measured spectral UV irradiance with Brewer instruments in Jokioinen (Mark III since 1995) and Sodankylä (Mark II since 1990). Additionally, a new Bentham DM150 was recently acquired for campaign use.

**Calibration activities**

FMI has a dark room UV calibration facility both in Jokioinen and Sodankylä. FMI has participated several UV measurement comparison campaigns, there it has been established that the quality of Finnish Brewer measurements is excellent and steady. The Brewer instrument of Jokioinen served as one of the core instruments of the QUASUME project (Quality Assurance of Spectral Ultraviolet Measurements in Europe). FMI is also responsible for calibration of the Antarctic NILU-UV instruments and data quality assurance.

**Satellite observations and instrument development**

FMI has a strong participation in three satellite instruments that are targeted for monitoring ozone in the atmosphere (GOMOS/Envisat, OSIRIS/Odin, OMI/EOS-Aura). The GOMOS instrument onboard the ESA’s Envisat satellite has been operating since spring 2002. Ozone profiles that cover the altitude range from upper troposphere to lower thermosphere during years 2002-2004 are already available. Due to the new measurement technique utilized by the GOMOS instrument the validation and the further development of the data processing algorithms of the GOMOS instrument has been intensive during the last years. Reprocessed data is expected at the end of 2005.

The OSIRIS instrument onboard the Swedish small satellite Odin has measured ozone profiles since 2001. The ozone profiles are processed also at FMI and during the last years the validation and optimization of the algorithms have taken place.

The Dutch-Finnish OMI instrument onboard the NASA’s EOS-Aura satellite has measured total ozone columns since 2004. FMI is hosting the OMI UV irradiance processing and archiving facility and the validation of the ozone and UV products are ongoing. In addition, local maps of total ozone columns and UV irradiance covering Central and Northern Europe are processed at FMI. These Very Fast Delivery products exploit the Direct Broadcast antenna at Sodankylä, Northern Finland. Once validated, the total ozone and UV irradiance maps are planned to be available in the Internet (omivfd.fmi.fi) within half an hour after the overpass of the satellite.

**RESULTS FROM OBSERVATIONS AND ANALYSIS**

Only Brewer UV measurements are considered to have a sufficient quality for assessment of long-term changes. The smaller the change is the longer time series is required for detection of it. A study on the Sodankylä UV time series 1990-2001 revealed no consistent trend during this 12 year period. An increase of UV levels were observed in early 1990s and then decrease towards the end of the period the largest values occurring in 1993 and after the cold winters of mid 1990s consistent with the ozone layer developments in the same period.

**THEORY, MODELLING, AND OTHER RESEARCH**

The modelling activities related to middle atmospheric ozone includes the use of a global 3D chemistry transport model of the stratosphere, a global stratospheric and mesospheric GCM and a model of the ionosphere. The modelling work includes both studies of long term trends of stratospheric ozone utilizing reanalyzed meteorological data (ERA-40) as well as process studies.
(PSC, chlorine activation, ozone loss rates). Also trajectory modelling is utilized for studying the ozone and water vapour distribution in the UTLS region. The scientific use of satellite measurements is increasingly important and an assimilation system combining OSIRIS and GOMOS profile data with a CTM model has been developed. In addition, the impact of solar proton events on the stratosphere and mesosphere is studied. In this study the unique night time ozone profile measurements of the GOMOS instrument are used. GOMOS data is also used for studying turbulence in the stratosphere.

FMI has developed models for reconstruction of the past UV time series as well as for assessment of the future UV levels. These data are essential for assessment of the long-term changes in surface UV. FMI contributed to the Arctic Climate Impact Assessment (ACIA) with a shared lead authorship of the chapter on ozone and UV. FMI has participated in multidisciplinary research projects that aim at better understanding of the effects of increased UV exposures on human health, terrestrial and aquatic ecosystems, or materials.

FMI coordinates the research project UVEMA exploring the Effects of UV radiation on MAterials. The study focuses on rubber compounds, natural fibre composites and carbon fibres provided by the industrial partners of the project. A programme of long-term outdoor material testing is being set up at seven European sites, including Jokioinen Observatory and Arctic Research Centre at Sodankylä. Prevailing UV radiation and weather conditions are being monitored alongside with the programme at each station. Exposed material samples will be investigated in respect of various properties: colour, quality/coarseness of the surface and compression/flexural/tensile strength. As an outcome, more reliable estimates for the useful lifetime of the materials are to be gained.

FMI Arctic Research Centre at Sodankylä hosts the experimental fields of FUVIRC-experiment (Finland UV International Research Centre) to study biological impacts of UV-B radiation to boreal plants at enhanced UV-radiation condition. There are two experimental sites representing typical landscape types of northern Fennoscandia, a boreal pine forest test field and peat land test field. Enhancement of the ambient UV-exposure can be regulated to desired values through extensive monitoring and control system. The field serves atmospheric chemistry, human health, and biological research initiatives by providing extensive UV monitoring data, guidance (i.e. calibration of instruments, maintenance of field test sites), and research facilities (i.e. laboratories, instruments, equipment and accommodation for visiting researchers).

DISSEMINATION OF RESULTS

Data reporting

FMI has participated in the Global Atmospheric Watch (GAW) programme since 1994. Within the programme, FMI maintains the Pallas-Sodankylä GAW station and conducts an extensive research programme related to atmospheric aerosols. Within this twin GAW station surface and boundary layer measurements are done in FMI clean air site of Pallas while upper air measurements, UV and Ozone monitoring takes place at Sodankylä. In upper air research Sodankylä functions as an auxiliary station in the global Network of Detection of Stratospheric Change.

FMI maintains the European UV Database (EUVDB). EUVDB is a regional WMO database containing some two million UV spectra. The UV spectra of the two Finnish Brewer instruments are submitted to EUVDB.

Regular ozone soundings have been performed at Marambio since 1988; the data has been used in scientific publications, and form a significant contribution to the WMO ozone bulletins (www.wmo.ch/web/arep/ozone.html).
Information to the public

FMI provides a 2-day forecast of the UV Index in Europe. The forecast, which is published in the internet, includes a contour map of the local solar noon maximum clear sky maximum UV Index. Additionally, local clear sky UVI forecast is provided for several sites in Finland and Europe. The Finnish broadband UVI measurements are also incorporated in the web page. FMI has actively participated in increasing the awareness of general public on the health effects of UV radiation. In addition, FMI contributed to the Arctic Climate Impact Assessment (ACIA) document with a shared lead authorship of the chapter on ozone and UV.

Ozone depletion has a large public interest due to related health (UV) and environmental issues, e.g. the unprecedented stratospheric conditions and severe ozone loss in the winter and spring 2004/2005 triggered a wide interest in the Finnish media. The major scientific results are published in international refereed journals and are also presented at relevant international conferences. Popularized information is distributed through press releases and interviews. Information about research activities as well as measurements and analysis results are also available through FMI web pages; Arctic and Antarctic research at FMI, www.fmi.fi/research_polar/polar.html, FMI-ARC observations and analyses, fmiarc.fmi.fi, Remote sensing projects and general Ozone and UV related information, www.fmi.fi/research_atmosphere/uvatmosphere.html.

Relevant scientific papers


PROJECTS AND COLLABORATION

The major national funding organisations are the Academy of Finland and the National Technology Agency of Finland. The Antarctic research related to ozone and UV and the as well as the research of the impact of solar proton events on stratosphere and mesosphere is partly funded by the Academy of Finland. FMI collaborates with the University of Helsinki in atmospheric modelling and in developing data retrieval methods and assimilation technique for the GOMOS and OSIRIS instruments.

- FARPOCC (Finnish Antarctic Research Programme on Polar Climate Change, [www.fmi.fi/research_polar/polar.html](http://www.fmi.fi/research_polar/polar.html))
- MAIST (Middle atmospheric interactions with sun and troposphere)
- FUVIRC (Finnish Ultraviolet International Research Center, [fuvirc.oulu.fi/index.htm](http://fuvirc.oulu.fi/index.htm))
- MUTUAL (Multiproxy Approach to Estimate Changes in UV Exposure in Arctic Lakes, [www.helsinki.fi/bioscience/ecru/projects/mutual.htm](http://www.helsinki.fi/bioscience/ecru/projects/mutual.htm))
- UVEMA (Effects of UV radiation on Materials, [uvema.fmi.fi/](http://uvema.fmi.fi/))

FMI has participated in several EU funded Arctic and Antarctic research projects including tasks such as stratospheric modelling and measurement campaigns. The modelling activities include cooperation with the National Center for Atmospheric Research, USA and Max-Planck Institute, Hamburg. Sodankylä has participated in all major European stratospheric ozone campaigns. In 1999 and 2003 the Marambio activities formed an important part of the international stratospheric ozone research campaigns.
QUASUME (Quality Assurance of Spectral Ultraviolet Measurements in Europe)

RETRO (REanalysis of the TROpospheric chemical composition over the past 40 years, retro.enes.org/)

CANDIDOZ (Chemical and Dynamical Influences on Decadal Ozone Change)

SCOUT-O3 (Stratospheric-Climatic Links with Emphasis on the Upper Troposphere and Lower Stratosphere, www.ozone-sec.ch.cam.ac.uk/)

PROMOTE (PROtocol MOntiToring for the GMES Service Element, www.gse-promote.org/)

ACIA (Arctic Climate Impact Assessment, www.acia.uaf.edu/pages/scientific.html)

COSMOS (Community Earth System Models, cosmos.enes.org)

FMI is hosting EUMETSAT Satellite Application Facility on Ozone Monitoring (O3M SAF, fmi.o3saf.fi). O3M SAF is one of the SAFs in EUMETSAT SAF network. SAFs are specialised development and processing centres within the EUMETSAT Application Ground Segment (www.eumetsat.int). O3M SAF is developed in co-operation with Koninklijk Nederlands Meteorologisch Instituut (KNMI), Deutsche Zentrum fur Luft- and Raumfahrt (DLR), Deutscher Wetterdienst (DWD), Aristotle University of Thessaloniki (LAP), Hellenic National Meteorological Service (HNMS), Danish Meteorological Institute (DMI), Meteo-France (M-F) and Koninklijk Meteorologisch Instituut (KMI).

The purpose of the O3M SAF is to produce a set of near real-time and offline products and validation services. Near real-time products are GOME-2 total ozone and ozone profiles, HIRS total ozone and UV clear-sky fields. Offline products derived from GOME-2 data are total column amounts of ozone, NO2, BrO, ozone profiles, aerosol index and optical depth and UV fields including cloudiness and albedo. The ozone and UV data will be validated against ground-based observations of total ozone and UV as well as balloon borne, microwave and lidar observations of the vertical distribution of ozone. An important part of the O3M SAF activities has been related to scientific work to develop radiative transfer calculation methods and other algorithms used for satellite ozone and related data retrieval.

The Satellite Data Centre of FMI-ARC started in 2002. The activities include a processing facility for the GOMOS/Envisat ozone instrument. The FMI-ARC data centre also process part of the OSIRIS/Odin ozone data. Data reception from the EOS-Aura satellite is also going on for Very Fast Delivery products of the total ozone and UV irradiance maps, to be available within half an hour after the overpass of the satellite.

FUTURE PLANS

Although the basic processes related to stratospheric ozone are now fairly well understood, there remain important research topics related to ozone and UV, such as the effects of increased UV-irradiance on nature and details of the complex interaction between ozone depletion and the greenhouse effect. According to the present understanding the recovery of the ozone layer will take several decades, therefore it is desirable that the research activities will be continued and developed.

In the near future the vortex build-up period in the winter polar stratosphere and interaction between ozone variations and vortex dynamics will be studied. FMI will also take part in several activities organized during the International Polar Year 2007/2008. To continue the high resolution ozone profile measurements of OSIRIS and GOMOS instruments FMI has proposed OLIVIA (Occultation and limb viewing of the atmosphere) instrument to the ESA Earth Explorer programme in 2005.

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FRANCE

Ozone and UV radiation research in France is managed by the CNRS – Institut National des Sciences de l’Univers (INSU) under a dedicated Programme National de Chimie de l’Atmosphère (PNCA). Long term monitoring activities relevant to NDSC are coordinated by the Institut Pierre Simon Laplace (IPSL). Space and balloon components are managed by the Centre National d’Etudes Spatiales (CNES). Additional contributions are provided by the Institut Paul Emile Victor (IPEV), Météo-France, the Ministère de l’Ecologie et du Développement Durable, the Ministère de la Recherche, the Institut National de Recherche Agronomique (INRA) and a number of Universities. Many of the above programmes are also supported by the European Commission under the 5th and 6th Environmental Programmes.

The research include the long term monitoring of the stratosphere and UV-B in the frame of NDSC at a variety of sites, the study of ozone depletion related mechanisms in polar areas, at mid-altitude and in the tropics using balloon, aircraft and space borne instruments, most of them being operated in cooperation with other European and international institutes.

OBSERVATIONAL ACTIVITIES

Ground-based

France is running two primary stations of the international Network for Detection of Stratospheric Change (NDSC) at the Observatoire de Haute Provence (OHP) and the Antarctic station of Dumont d’Urville (DDU), a complementary site at Reunion Island in the Indian Ocean and a number of instruments at other locations in cooperation with local institutes: a lidar at Alomar in Norway and the SAOZ UV-Vis spectrometers at Scoresbysund (Greenland), Sodankyla (Finland), Salekhard and Zhigansk (Federation of Russia), Bauru (Brazil), Tarawa (Republic of Kiribati) and Kerguelen Island.

The list of instruments at OHP includes a series of lidar for stratospheric temperature, aerosol, stratospheric and tropospheric ozone and water vapour, a SAOZ UV-Vis spectrometer, a BrO UV spectrometer of IASB-BIRA in Belgium, an automated Dobson from NOAA, weekly ozonesondes and a spectral UV-B monitor at the nearby Alpine station of Briancon. Additional Dobson measurements conducted previously at Bordeaux have been moved to Lanemezan.

In Antarctica, the instruments operating since 1988 are a PSC / aerosol lidar in cooperation with the Italian CNR, a SAOZ, a UV-B monitor and ozonesondes at Dumont d’Urville. The ozone lidar closed in 2001, has bee replaced in 2005. An additional SAOZ is in operation since 1995 at the sub-Antarctic Island of Kerguelen. The installation of a SAOZ and a microwave radiometer are anticipated at the inland French-Italian station of Concordia expected to run year round after 2006.

At the tropical site of Reunion Island, the instruments operating are a temperature / aerosol lidar, stratospheric and tropospheric ozone lidars, a SAOZ and weekly ozone sondes. A high altitude station is under construction at Maido at 2500 m asl for hosting all previous instruments after 2006 together with a microwave radiometer for ozone and water vapour and a FTIR operated by the Belgium IASB-BIRA.

France is also responsible for the temperature lidar measurements at the Norwegian-German lidar station of ALOMAR in Norway.

While part of the data (SAOZ ozone / NO₂ and ozonesondes) are made available in near real time to WMO and to the European data base at the Norwegian Institute for Air Research (NILU) for research programmes and satellite validation, they are made publicly available after reprocessing through the NDSC archive centre.
Summary of Ground-based observations

**Column measurements of ozone and other gases /variables relevant to ozone loss**

- SAOZ Ozone and NO2 at Scoresbysund (Greenland), Sodankyla (Finland), Salhekar (W. Siberia-), Zhigansk (E. Siberia), OHP (France), Bauru (Brazil), Reunion Island, Kerguelen and Dumont d’Urville (Antarctica)
- Dobson at OHP and Lanemezan (France)

**Profile measurements of ozone and other gases /variables relevant to ozone loss**

- Stratospheric Ozone lidar at OHP (France) and Dumont d’Urville (Antarctica)
- Ozonesondes at OHP (France), Reunion Island and Dumont d’Urville
- Stratospheric temperature lidar at at OHP (France), Reunion Island and Alomar (Norway)
- Aerosol lidar at OHP (France), Reunion Island and Dumont d’Urville
- Tropospheric ozone lidar at OHP (France) and Reunion Island

**UV measurements**

- Broadband measurements at Dumont d’Urville (Antarctica)
- Spectroradiometers at Villeneuve d’Asq and Briançon (France)

**Calibration activities**

- NDSC intercomparison campaign of UV-Vis instruments in Norway, and ozone lidar intercomparison at OHP.

**Satellites**

Relevant to stratospheric ozone research, a variety of space activities have been carried out in France under the auspices of CNES:

- the scientific exploitation of the data of the Polar Ozone and Aerosol Monitoring (POAM) instruments of the Naval Research Laboratory in the United States placed on board the French CNES satellites (POAM II on SPOT III in 1994 and POAM III on SPOT IV in 1998), from which ozone destruction rates in the Arctic have been derived;
- the analysis of the measurements of the SMR instrument (ozone, water vapour and ClO) on board the Swedish-Finnish-Canada-French ODIN satellite placed in orbit in 2001 and still operating;
- the exploitation of the data of the French initiated GOMOS instrument on board the ESA ENVISAT satellite in orbit since March 2002, and more generally a participation to that of the two other stratospheric chemistry instruments MIPAS and SCIAMACHY; and,
- a strong involvement in the validation of the measurements of GOME-ERS-2, ODIN and ENVISAT from ground based and dedicated balloon flights measurements in the Arctic, at Mid-latitude and in the tropics

Finally, Météo-France is contributing to the preparation of EUMETSAT’s Ozone Monitoring Satellite Application Facilities hosted by the Finnish Meteorological Institute. This facility will deliver ozone and minor constituents products derived from the GOME-2 and HIRS instruments on board METOP, the European meteorological polar platform to be launched in 2006. The derivation of ozone columns in the lower stratosphere from METEOSAT Second Generation and for METOP/HIRS is the specific contribution of Météo-France.
Aircraft

The two French research aircraft have been renewed for an ATR 42 and a Falcon 20, both anticipated starting operating in early 2006. France is also running since 1993 in cooperation with other European institutes and with support of the European Commission, the MOZAIC programme of in situ ozone, water vapour and NOy (since 2002) measurements on in-service commercial aircraft, from which tropospheric ozone climatology are derived at a number of airport worldwide.

Balloons

The French contribution to stratospheric balloon activities is twofold: CNES balloon operations in France, Sweden and Brazil for a number of European and international scientists, and development of scientific instruments designed for ozone related research at French laboratories.

The balloons used during the past several years include large open stratospheric balloons carrying heavy (500-600 kg) payloads for few hours (20 flights/year), small flexible and cheaper balloons which could be flown more frequently particularly in the Arctic in the winter for studying fast chemical changes (20 flights/year) and long duration balloons of two types: Infra-Red Montgolfier carrying 60 kg at 25 km flown for few weeks in the Arctic or in the tropics, and constant level super-pressure balloons carrying 20 kg at 19 km for few weeks.

Stratospheric chemistry instruments developed in France include: a FTIR (LPMA) for measuring profiles of long lived, reservoir and radical species; a tuneable diode laser system (SPIRALE) for the in-situ measurement of NOx and NOy species; a star occultation UV-Visible spectrometer (AMON) for the night-time measurement of O3, NO2, NO3 and OClO; and several light weight instruments flown more frequently on small balloons together with other European instruments at a variety of sites: the SAOZ UV-visible spectrometer for O3, NO2, BrO and OClO by solar occultation; the SALOMON moon occultation version; the SDLA diode laser for in-situ CH4, CO2 and water vapour; and the Rumba meteorological payload for long duration balloons.

Most recent balloon campaigns relevant to stratospheric dynamics and chemistry were:

- a European VINTERSOL campaign in the Arctic during the winter of 2002/2003 for the validation of ENVISAT, SAGE III and ILAS II as well as studying ozone depletion;
- an ESA-CNES ENVISAT validation campaign of long duration MIR balloon flights in Bauru (22°S) in Brazil in February 2003;
- a European HIBISCUS campaign of 18 short and long duration circumnavigation balloon flights at the tropics in Brazil in January-March 2004 for studying the impact of deep convection on the stratosphere;
- an ESA-CNES ENVISAT validation campaign of 5 large balloon flights in Teresina, Northern Brazil in June-July 2005;
- a VORCORE project of 20 long duration constant level balloon currently held (September 2005) in Antarctica for studying the dynamics of stratospheric vortex.

Planned in the 2006 is a balloon / aircraft campaign in West Africa in the frame of the new European FP6 SCOUT-O3 project for studying the Stratospheric Chemistry-Climate relationship.

Data interpretation, exchange and archival

Though the data are analysed through many cross-exchanges with international scientists and particularly Europeans within cooperative projects, France institutes have developed a full set of models ranging from Lagrangian, 3-D chemical transport (CTM), contour advection, meso-scale and assimilation models. While the experimental data as well the results of modelling relevant to European projects are archived into the NILU data base available through appropriate protocols, all
French space and field data relevant to the stratosphere are archived into a newly built national data base ETHER.

RESULTS FROM OBSERVATIONS AND ANALYSIS

A number of studies are being conducted based on the above observational data frequently in collaboration with foreign scientists and particularly European institutes within projects supported the European Commission. Among those studies, two are highlighted here as an illustration.

Figure 1 shows the results of the yearly evaluation of total ozone loss in the Arctic stratosphere since 1993 from the SAOZ ground based network illustrating the large inter-annual variability of the ozone destruction in relation with the meteorology of the vortex.

![Figure 1: Estimation of amplitude of chemical stratospheric ozone reduction the Arctic during the winter season from the measurements of the SAOZ network. Left: minimum ECMWF temperature north of 60°N at 475 K and 550 K; Right ozone chemical reduction after subtraction of the contribution of transport using a 3D CTM model. [Goutail et al., 2005].](image)

Figure 2 shows a comparison of the 1985-2003 ozone concentration profiles trends above the Observatoire de Haute Provence evaluated from SAGE 2 and lidar observations. Although the exact figure depends a little on the period selected for the analysis, a consistent reduction of 4-7% / decade could be derived from both data sets in the upper stratosphere, and still of 1-3% at lower altitude.
DISSEMINATION OF RESULTS

Data reporting

The SAOZ (ozone / NO₂) and ozonesondes data are made available in near real time to WMO, WOUDC and the ESA and EC data –bases at the Norwegian Institute for Air Research (NILU). All NDSC relevant data are deposited, after reprocessing, in the NDSC archive centre. In addition all French space and field data relevant to the stratosphere are archived into a national data base ETHER.

Relevant scientific papers


Figure 2: Stratospheric ozone reduction since 1985 above the OHP station in France derived from Lidar and SAGE II observations [Godin et al. 2005].


FUTURE PLANS

NDSC ground-based observations will be continued at OHP, Reunion Island, Dumont d’Urville as well as at the SAOZ stations. The two new coming NDSC relevant projects are: (i) the beginning of the construction of the high altitude (2500 m asl) Maido station at Reunion Island planned to host a FTIR of the Belgium IASB, and a microwave radiometer of the Laboratoire d’Aerologie in Toulouse; (ii) the opening of the Concordia station inland Antarctica for its first wintering in 2005, where the installation of a SAOZ spectrometer is planned in 2006, followed later by an ozone/ water-vapour microwave radiometer.

The analysis, interpretation and modelling of most of French stratospheric ozone relevant ground-based, satellite, aircraft and balloon observational projects are part of the SCOUT-O3 FP6 project (2004-2009) supported by the European Commission and coordinated by the University of Cambridge (UK).
GEORGIA

INTRODUCTION

In Georgia the examination of the atmospheric ozone (total ozone, ozone vertical distribution and surface ozone concentration) were started almost 50 years ago. Several decades were conducted only scientific studies of atmospheric ozone.

Later the Cabinet of Ministers of Republic of Georgia decided in Decision N711 of 8 November, 1995 that Georgia shall accede to "the 1985 Vienna Convention for the Protection of the Ozone Layer" and "the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer". On 21 March, 1996, Georgia acceded to these international documents and sufficiently these documents entered into force for Georgia on 19 June, 1996.

The National Country Programme for phasing out of ODSs was developed jointly with the scientific study programmes of ozone and approved in 1997 through assistance of United Nations Environment Programme and United Nations Development Programme and financial support of Multilateral fund so as to enable the country to implement obligations under the Montreal Protocol on the Substances that Deplete the Ozone Layer. The institutional framework was established to ensure the implementation of the Action Plan in the Country Programme. The National Ozone Unit the Ministry of Environment Protection and Natural Resources of Georgia is a coordinating body for the implementation of all activities under the Montreal Protocol.

OBSERVATIONAL ACTIVITIES

Column measurements of ozone and other gases/variables relevant to ozone loss

The regular observation of total ozone started at Abastumani Astrophysical Observatory of Academy of Sciences of Georgia (41° 45' N, 42° 50' E, 1600 m asl) in 1957. A second station was established in Tbilisi (41° 41' N, 44° 57' E, 450 m asl) by the Hydrometeorological Service of Georgia in 1964. Total ozone observation were also carried out at the observational post of the Institute of Geophysics of Academy of Sciences of Georgia in Telavi (41° 48' N, 45° 30' E, 600 m asl) from 1973 till 1987. All observations are carried with ozonemeters of M-124 type constructed in the Main Geophysical Observatory (MGO) in St. Petersburg (Russia).

Regrettably, both Tbilisi ozonemeters were broken in 2001. At present only Abastumani ozonemeter is under working conditions.

The regular measurements are conducted of surface ozone concentration with the use of the OMG-200 type ozonemeter since 1980 to the present in Tbilisi and Telavi.

Note

Using standard actinometrical observations for eight Georgian locations (Tbilisi,1928-1991; Telavi, Tsalka – 1457 m, Anaseuli – 158 m, Senaki – 40 m, Sukhumi – 116 m -in the mid. 1950 – 1991; Jwari Pass – 2396 m, 1973 – 1985; Kazbegi – 3656 m, 1955-1964), the Atmospheric Aerosol Optical Depth was established (Institute of Geography and Institute of Geophysics of Academy of Science of Georgia). In 1991, actinometrical observations were stopped because the instruments were not tested.

The measurements were renewed of the Atmospheric Aerosol Optical Depth from 2003 in Tbilisi (Institute of Geography and Institute of Geophysics of Academy of Science of Georgia).
Profile measurements of ozone and other gases/variables relevant to ozone loss

The vertical distribution of ozone in Georgia by optical method and with the electrochemical ozonesondes was carried out in 1973-1982. In recent years, such measurements are not conducted.

Note

The photometric measurements of twilight sky brightness in different narrow intervals of the visible spectrum have been carried out in Abastumani Astrophysical Observatory since 1940. Such measurements allow to determine aerosol loading in the stratosphere and mesosphere as a function of height.

UV measurements

Unfortunately, UV- measurements in Georgia are not conducted because of the absence of equipment.

Calibration activities

The calibration of the ozonemeters was made every two years in the MGO during the existence of the former Soviet Union. After 1990 due to financial difficulties the calibration of Abastumani ozonemeter was carried out only in 1994, the calibration of ozonemeter of the Institute of Geophysics did not calibration after 1988, the calibration of Tbilisi ozonemeter was carried in 1999. Therefore, at present the Abastumani ozonemeter dates of total ozone in Georgia are unreliable.

The calibration of actinometer was carried out in 2002 years through the financial support Institutional Straitening Project of UNEP and NOU of Georgia.

RESULTS FROM OBSERVATIONS AND ANALYSIS

In recent years is continued the study of long-term variations of atmospheric ozone (total and surface) and aerosol in Georgia and their connection with human health, photochemical smog in the atmosphere of Tbilisi and its influence on the people health, quasi-biennial variations of the stratosphere ozone and solar activity, the evaluation of the influence of lasting variations in the total ozone content on the changeability of the regime of biologically active ultraviolet solar radiation in Georgia, radioactively active small atmospheric admixtures climatic effects in Georgia, Interaction of the ozone and aerosol, etc. The enumeration of the published works is represented lower.

THEORY, MODELLING, AND OTHER RESEARCH

Calculation of the effect some radiatively active small atmospheric admixtures on the direct and diffuse solar radiation in Georgia have been carried out for the clear sky conditions. Estimation of the effect of the variations of water vapour, total ozone, aerosols in the atmosphere and underlying surface albedo on the short-wave solar radiation were given (see [14,19,22]).

DISSEMINATION OF RESULTS

Data reporting

The total ozone data of Tbilisi station (including 2000 year) are regularly (every day) sent to the Main Aerological Observatory near Moscow, where all analogous information received from the countries of the Commonwealth of Independent States is collected. Twice a year the daily total ozone values are sent to the Main Geophysical Observatory in St. Petersburg. These data after
quality control in MGO are sent to the WMO World Ozone and UV Data Centre (WO3UDC) in Toronto.

The total ozone data of Abastumani station are kept in the Abastumani astrophysical observatory in the tables form. The total ozone data of Telavi and surface ozone concentration data of Tbilisi and Telavi are kept in the Institute of Geophysics in the tables form and computer data base form.

The Atmospheric Aerosol Optical Depth data are kept in Institute of Geography and Institute of Geophysics in the computer data base form.

The stratosphere and mesosphere aerosol data are kept in Abastumani astrophysical observatory in the tables and computer data base form.

Information to the public

The National Ozone Unit the Ministry of Environment Protection and Natural Resources of Georgia on regular bases (3 times per year) publishes UNEP OzonAction bulletin in the Russian language. The popular book “Twenty questions and answers about the ozone layer” was produced by NOU in Georgian language in 2005. Institute of geophysics through the press and television inform the population of Georgia about the ecological problems, connected with atmospheric ozone (not regularly)

Relevant scientific papers

The results of the research works are published in the form of two monograph and in more than one hundred various articles. The most recent ones are:


Kharchilava J., Chikhladze V. – The basic chemical reactions of formation and disintegration of ozone and estimation of their constants in the lower polluted layer of tropospheric air in conditions of Tbilisi,
<table>
<thead>
<tr>
<th>Research Programme:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PROJECTS AND COLLABORATION</strong></td>
</tr>
<tr>
<td><strong>Time variations of the total ozone and the surface ozone in several regions of Georgia and their dependence on the atmospheric processes;</strong></td>
</tr>
<tr>
<td><strong>Trends and decline of the total ozone;</strong></td>
</tr>
<tr>
<td><strong>Interaction of the stratospheric and tropospheric ozone;</strong></td>
</tr>
</tbody>
</table>
• Increasing of surface ozone in Georgia and conditions for appearance of photochemical smog;
• Effect of ozone on local climate;
• Ozone, aerosols and ecosystem;
• Total ozone and solar activity;
• Vertical aerosol distribution in the stratosphere and middle atmosphere by the twilight sounding method;
• Effect of ozone and atmospheric aerosol on the direct and diffuse solar radiation including ultraviolet radiation.

FUTURE PLANS

• Installation of equipment for monitoring regularly total ozone, ozone vertical distribution, surface ozone, tropospheric and stratospheric aerosols, atmospheric aerosol optical depth;
• To continue research programme;
• Laboratory modelling interaction ozone with small atmospheric admixtures (aerosols, gases);
• Laboratory modelling interaction UV radiation with ozone, cloudiness, aerosols and gases.
• The organization of regular information campaign for the population of Georgia via the mass media on dangerous levels of surface ozone, solar UV-radiation and prophylaxis measures for mitigation of their negative effect.

NEEDS AND RECOMMENDATION

• There is an urgent need for financial assistance intended for the reparation of two ozone instruments M-124 and calibration of four ozone instruments M-124;
• There is an urgent need to purchase one or two more modern total ozone instrument and two or three UV-B solar radiation instruments;
• There is no funds available for periodic calibration of standard actinometrical instruments;
• A standard Dobson or Brewer spectrophotometers and more modern surface ozone instruments are essential to have in the future.

****
In accordance with Decision VCV/3: Recommendations of the fifth meeting of the Ozone Research Managers to the Parties of the Vienna Convention at Geneva in 2002, the following significant research and monitoring activities have been carried out since 2002 in Germany.

Ozone-monitoring and related research in Germany is distributed over numerous institutions. Usually, there is no distinct separation between research and development, monitoring and quality control. In general, research is carried out at university institutes or at research centers (MPI, DLR, FZ-Karlsruhe, FZ-Jülich). Regular long-term monitoring of ozone outside the planetary boundary layer is provided by DWD and AWI, UV-monitoring by BfS, UBA and DWD. Surface ozone is monitored by authorities at the national and federal level. Surface ozone will not be discussed further in this report.

Table 1: Overview of institutes involved in ozone/UV research (R), development (D), modeling (MD), monitoring (MT), quality assessment/quality control (QA/QC).

<table>
<thead>
<tr>
<th>Institute</th>
<th>Location</th>
<th>Field</th>
<th>Keywords</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deutscher Wetterdienst, <a href="http://www.dwd.de/en/FundE">www.dwd.de/en/FundE</a></td>
<td>Hohenpeissenberg, Lindenberg</td>
<td>MT, R, QA/QC</td>
<td>Regional Ozone Center, DCC, NDS, GAW</td>
</tr>
<tr>
<td>Forschungszentrum Jülich, <a href="http://www.fz-juelich.de/">www.fz-juelich.de/</a></td>
<td>Jülich</td>
<td>R, QA/QC, MD</td>
<td>Calibration O$_3$-Sonde, JOSIE, ClaMS</td>
</tr>
<tr>
<td>MPI f. Meteorologie (DKRZ), <a href="http://www.dkrz.de/">www.dkrz.de/</a></td>
<td>Hamburg</td>
<td>R, MD</td>
<td>ECHAM</td>
</tr>
<tr>
<td>IAP Kühlungsborn, <a href="http://www.iap-kborn.de/">www.iap-kborn.de/</a></td>
<td>Kühlungsborn</td>
<td>R, D, MT</td>
<td>Middle Atmosphere, Alomar</td>
</tr>
<tr>
<td>Bundesamt f. Strahlenschutz (BfS) <a href="http://www.bfs.de/">www.bfs.de/</a></td>
<td>Salzgitter</td>
<td>MT</td>
<td>UV</td>
</tr>
<tr>
<td>Umweltbundesamt, <a href="http://www.umweltbundesamt.de/">www.umweltbundesamt.de/</a></td>
<td>Berlin</td>
<td>MT,</td>
<td>Air quality</td>
</tr>
<tr>
<td>Uni Bremen, IUP, IFE, www-iup.physik.uni-bremen.de/index.html</td>
<td>Bremen</td>
<td>R, D</td>
<td>GOME, SCIAMACHY, MICROWAVE</td>
</tr>
<tr>
<td>Uni Köln, Inst. f. Meteorologie, <a href="http://www.uni-koeln.de/math-nat-fak/geomet/">www.uni-koeln.de/math-nat-fak/geomet/</a></td>
<td>Köln</td>
<td>R, MD</td>
<td>EURAD,</td>
</tr>
<tr>
<td>Uni Heidelberg, <a href="http://www.uphys.uni-heidelberg.de/">www.uphys.uni-heidelberg.de/</a></td>
<td>Heidelberg</td>
<td>R, QA/QC</td>
<td>DOAS</td>
</tr>
<tr>
<td>IMK, Forschungszentrum und Universität Karlsruhe, www-imk.physik.uni-karlsruhe.de/</td>
<td>Karlsruhe, Garmisch-Partenkirchen (IFU)</td>
<td>R, D, MD, MT, QA/QC</td>
<td>FTIR, MIPAS, ENVISAT,</td>
</tr>
<tr>
<td>Uni München (LMU)</td>
<td>München</td>
<td>R, MD</td>
<td>UV, STAR</td>
</tr>
<tr>
<td>Uni Hannover, Inst. f. Meteorologie <a href="http://www.muk.uni-hannover.de">www.muk.uni-hannover.de</a></td>
<td>Hannover</td>
<td>R</td>
<td>UV</td>
</tr>
</tbody>
</table>
MONITORING

Germany's Meteorological Service (DWD) is running a very intense measurement programme at the Observatories Hohenpeissenberg and Lindenberg, monitoring the ozone vertical distribution and total ozone columns on a regular and long-term basis (Table 2). Special efforts are put into high quality and long-term consistency. The time series cover 38 years for ozone measurements up to 30 km altitude (balloon-sonde and Dobson-spectrometers) and 18 years for upper stratospheric LIDAR observations. Data are regularly submitted to the data centers at Toronto, Thessaloniki, NILU, and NDSC. In addition to the observational UV-network of the BfS (Table 2), DWD continues to measure UV-B radiation for research and development purposes. Both institutes provide the public with UV-information including daily forecasts of the UV-index (see below).

The Alfred Wegener Institute for Polar and Marine Research (AWI) is very active in atmospheric research. It operates two fully equipped polar stations in the Arctic (Ny-Ålesund/Koldewey - NDSC primary station), and Antarctic (Neumayer) and temporary onboard of RV POLARSTERN. The Neumayer meteorological observatory is designed as a radiation and climate monitoring station and an air chemistry observatory. In the next years a new station (Neumayer III) will replace Neumayer II to continue the long-term observations. This includes measurements of surface radiation as part of a global observation network to detect long-term changes in the Earth's radiation budget and their impacts on climate (BSRN). Since 1992 vertical ozone balloon soundings are part of the regular observations. These measurements continue the sounding record from the former station Georg Forster, beginning in 1985.

The full suite of NDSC measurements are routinely performed at the primary station Koldewey. This includes ozone-soundings by ECC-sondes, Lidar, microwave, DOAS, FTIR and UV-spectrometers. In addition, the same radiation measurements as at Neumayer-Station are performed as part of the BSRN.

IMK (Forschungszentrum and University of Karlsruhe) contributes with ground based remote sensing observations by FTIR- and mm- spectrometers and LIDAR instruments within the NDSC and WMO-GAW networks to trend assessments. With a new tropical mm-spectrometer station in Merida, Venezuela, 4700 m asl, FZK-sites cover tropical, sub-tropical, mid- and polar latitudes. Within the NDSC, FTIR spectrometers are operated by IMK at Kiruna (North of Sweden) and at Izaña on Tenerife Island and a primary NDSC station at the Zugspitze. Several ozone- and climate-related species are measured with this technique since about 10 years. The stratospheric aerosol content is monitored since 1976 with a LiDAR which is part of the NDSC at the Garmisch site.

Two major satellite instruments onboard the European ENVISAT satellite, MIPAS and SCIAMACHY, are initialized and supported by groups at IUP/IFE, University of Bremen, and IMK, Karlsruhe. DLR/DFD is routinely retrieving and processing the data from a number of satellite instruments, among them GOME, SCIAMACHY, and MIPAS. In order to improve the utilization of data, the World Data Center for Remote Sensing of the Atmosphere (WDC-RSAT) was established.

The primary focus of WDC-RSAT is the provision of data which are primarily gathered from satellite based sensors. Higher level data and information products are also generated from the data through assimilation into numerical models of the atmosphere and of its interaction with the biosphere.

WDC-RSAT grew out of the Atmos Users Center (AUC) of the German Remote Sensing Data Center which was established to provide the European atmospheric satellite data user community with direct and easy access to measurements and derived data products from a wide range of sensors.

In addition to providing sensor data and analysis products of the atmosphere, WDC-RSAT offers various services such as the assistance of scientific field campaign planning by e.g.
analyzing the overall atmospheric state. Additionally offered is a service contributing to validation of atmospheric measurements through application, for example, of a 3D trajectory model such that satellite data can be better matched with correlative measurements.

Table 2: Operational network for long-term measurements of ozone and UV.

<table>
<thead>
<tr>
<th>Type of observation</th>
<th>Location</th>
<th>Org.</th>
<th>Instrument</th>
<th>Type</th>
<th>Start</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Ozone Column</td>
<td>Hohenpeissenberg</td>
<td>DWD</td>
<td>Dobson No. 104, No. 064</td>
<td>1967</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hohenpeissenberg</td>
<td>DWD</td>
<td>Brewer No. 010</td>
<td>1983</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hohenpeissenberg</td>
<td>DWD</td>
<td>Microtops No. 3128, No. 3785</td>
<td>1996</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lindenberg</td>
<td>DWD</td>
<td>Brewer No. 078</td>
<td>1992</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Potsdam</td>
<td>DWD</td>
<td>Dobson No. 071</td>
<td>1964</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Potsdam</td>
<td>DWD</td>
<td>Brewer No. 030</td>
<td>1987</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Potsdam</td>
<td>DWD</td>
<td>Brewer No. 118</td>
<td>1996</td>
<td></td>
</tr>
<tr>
<td>Calibration</td>
<td>Hohenpeissenberg</td>
<td>DWD</td>
<td>Dobson No. 064</td>
<td>1999</td>
<td></td>
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<tr>
<td>Ozone Vertical Profile</td>
<td>Hohenpeissenberg</td>
<td>DWD</td>
<td>Ozonesonde Brewer-Mast</td>
<td>1967</td>
<td></td>
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<tr>
<td></td>
<td>Hohenpeissenberg</td>
<td>DWD</td>
<td>LIDAR (Stratosphere) DIAL</td>
<td>1987</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lindenberg</td>
<td>DWD</td>
<td>Ozonesonde ECC (since 1992)</td>
<td>1974</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ny Alesund (Spitzbergen)</td>
<td>AWI</td>
<td>Ozonesonde ECC</td>
<td>1990</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ny Alesund (Spitzbergen)</td>
<td>AWI</td>
<td>LIDAR DIAL</td>
<td>1991</td>
<td></td>
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<tr>
<td></td>
<td>Neumayer (Antarctica)</td>
<td>AWI</td>
<td>Ozonesonde ECC</td>
<td>1992</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Garmisch</td>
<td>FZK</td>
<td>LIDAR (Troposphere) DIAL</td>
<td>1988</td>
<td></td>
</tr>
<tr>
<td>Calibration</td>
<td>Jülich</td>
<td>FZ</td>
<td>Ozonesonde</td>
<td></td>
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<tr>
<td>UV</td>
<td>Garmisch</td>
<td>FZK</td>
<td>Bentham DTM 300</td>
<td>1994</td>
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<td></td>
<td>Hohenpeissenberg</td>
<td>DWD</td>
<td>Brewer MK II No. 010</td>
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<td>Lindenberg</td>
<td>DWD</td>
<td>Brewer MK IV No. 078</td>
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<td></td>
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<td>DWD</td>
<td>Brewer MK II No. 030</td>
<td>1993</td>
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<td></td>
<td>Potsdam</td>
<td>DWD</td>
<td>Brewer MK III No. 118</td>
<td>1996</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Potsdam</td>
<td>DWD</td>
<td>Bentham DM 150</td>
<td>2000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Potsdam</td>
<td>DWD</td>
<td>Spectro 320D</td>
<td>2002</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dortmund</td>
<td>BAuA</td>
<td>Bentham DM150</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kulmbach</td>
<td>LU</td>
<td>Bentham DM150</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>München</td>
<td>BfS</td>
<td>Bentham DM150</td>
<td>1993</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Langen</td>
<td>BfS</td>
<td>Bentham DM150</td>
<td>1993</td>
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<tr>
<td></td>
<td>Schauinsland</td>
<td>BfS</td>
<td>Bentham DM150</td>
<td>1993</td>
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<tr>
<td></td>
<td>Sylt</td>
<td>CAU</td>
<td>Bentham DM 300</td>
<td>1995</td>
<td></td>
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<tr>
<td></td>
<td>Zingst</td>
<td>BfS</td>
<td>Bentham DM150</td>
<td>1993</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Zugspitze</td>
<td>FZK</td>
<td>Bentham DTM 300</td>
<td>1995</td>
<td></td>
</tr>
</tbody>
</table>

RESEARCH AND DEVELOPMENT

The German Ministry of Education and Science (BMBF) has been funding a number of ozone and UV-research programmes. These programmes were conducted in close cooperation with partners from Europe and abroad, and include laboratory studies, modeling and the evaluation of existing data. They substantially improve the understanding of the ozone layer, especially at northern high and mid-latitudes. The AFO 2000 Programme, in particular the KODYACS project has investigated the links between long-term ozone depletion and climate change. KODYACS combined substantial modeling efforts (ECHAM/CHEM) with analysis of existing long-term measurements.

Apart from ongoing ozone related research activities, DLR-IPA is involved in two major EU-funded projects: DLR-IPA is coordinator and one of the main contributors for the international TROCCINOX project. TROCCINOX is aimed at improving the knowledge about trace gases (including water vapor) and particles (ice crystal and aerosols) in the upper troposphere and lower stratosphere in connection with tropical deep convection as well as large scale upwelling motions. A major focus is on production of NOx by lightning (LNOx) in tropical thunderstorms. In two major international campaigns (January to March 2004, and January to March 2005), several aircraft,
including Brazilian Bandeirante, DLR-Falcon and Russian high-altitude Geophysica were deployed over Brazil, and on transfer flights across the Atlantic.

DLR-IPA and the Atmospheric Chemistry Department of the Max Planck Institute for Chemistry in Mainz are partners in the SCOUT-O3 project. SCOUT-O3's aim is to provide predictions about the evolution of the coupled chemistry/climate system, with emphasis on ozone change in the lower stratosphere and the associated UV and climate impact. In cooperation with FU-Berlin, DLR-IPA is leading SCOUT-O3 activity 1, which will generate ozone, climate and UV predictions with various state-of-the-art models. DLR-IPA is also involved in the major international SCOUT-O3 tropical thunderstorm campaign, November/December 2005 in Darwin (Australia), and in measurement and modeling activities for surface UV. IUP-Uni Bremen is one of the leading institutes in the scientific design of the GOME and the SCIAMACHY instruments. Algorithms for retrieving trace gas amounts from the instruments' raw data are developed in cooperation with German Remote Sensing Data Center (DFD), the Smithsonian Astrophysical Observatory (Harvard, Cambridge/MD, USA), the University of Heidelberg (Germany), the Koninklijk Nederlands Meteorologisch Instituut (KNMI, The Netherlands), and other institutes from the GOME Science Advisory Group.

IUP-Uni Bremen substantially contributes to the NDSC and operates a number of relevant systems at the KOLDEWEY Arctic station in cooperation with AWI. The building of a new tropical station (Merida, Venezuela, 4700 m asl) in cooperation with FZ Karlsruhe and AWI is in progress. They are also contributing to another arctic station on the Greenland ice-shelf (at 3200 m asl) in cooperation with DPC, Kopenhagen, Uni Bordeaux, Uni Leeds and NSF USA (EU-Project).

At IMK (Forschungszentrum and University of Karlsruhe) measurements of ozone and ozone relevant species have been performed for many years by ground-based and airborne observations. Since the successful launch of the ENVISAT satellite, the retrieval of MIPAS-ENVISAT data beyond ESA standard products with the KOPRA-RCP processor developed at IMK provides data sets on a global scale of NO, NO2, N2O5, HNO4, ClONO2, ClO, many other chlorine species, atmospheric tracers, other atmospheric parameters like photolysis rates and cloud particle properties (PSC, SVC). Main results are a detailed analysis of mixing effects during the Antarctic vortex split period in 2002, a global picture of PSC occurrence in the Antarctic, and the chemical effects of the strong solar storm events in fall 2003 and Arctic winter 2003/2004, showing ozone loss of 30% in about 50 km altitude. Balloon-borne observations allowed further analysis of the composition of PSC particles, ground based studies analyzed ozone loss in several winters. A new container with many new instruments has been developed for measurements on board a passenger aircraft Airbus A340-600 of Deutsche Lufthansa AG to measure regularly the distribution of ozone and other trace gases in the tropopause region.

The Lidar observation at Garmisch shows that the stratospheric aerosol load has relaxed after the eruption of Mt. Pinatubo. Current background levels are comparable to that observed in the seventies. Possible contributions from air traffic can therefore be excluded. Around 1995/1996 the Zugspitze and Jungfraujoch solar FTIR observations of total HCl and ClONO2 have monitored the Cl\textsubscript{\textgamma}-turnover as a response to the Montréal protocol.

At Forschungszentrum Jülich various research activities related to stratospheric ozone are carried out including in-situ and remote observations and model simulations. In-situ observations of stratospheric water vapor and halogen oxides (ClO, ClO\textsubscript{2}, BrO) are made from aircraft and balloon platforms. Remote observations of various chemical species from aircraft (M55-Geophysica) are performed with the IR spectrometer CRISTA-NF. 3-dimensional simulations with respect to chemical ozone loss and the ozone budget are performed with the Lagrangian CTM CLaMS. Also different methods for diagnosing chemical ozone loss from available observations have been developed and are applied.

Under the coordination of Forschungszentrum Jülich (FZJ) the European IAGOS (Integration of Routine Aircraft Measurements into a Global Observing System) project (http://www.fz-juelich.de/icg/icg-ii/iagos/) started in the beginning of 2005 with the preparation of a
distributed infrastructure for observations of atmospheric composition (e.g. ozone) on the global scale from commercial in-service aircraft. Commercial aircraft are complementary to satellite, balloon borne and ground based observations and can constitute an important component in a future integrated global observation system to watch the atmosphere for global or regional changes in the frame of the WMO/IGACO-(Integrated Global Atmospheric Chemistry Observations) theme. The IAGOS-initiative goes beyond the European MOZAIC (Measurement of Ozone by Airbus In-Service Aircraft) project (http://www.aero.obs-mip.fr/mozaic/), where five Airbus A340 long range passenger aircraft are equipped with automated instrumentation to measure comprehensive climatologies of the large scale distribution of ozone between surface and 12 km altitude since 1994. FZJ has been involved in MOZAIC from very beginning (coordination by CNRS in France). In total, more than 25,000 long-haul flights have been accomplished between 1994 and 2004 for O3 measurements, yielding more than 100,000 hours of data from the tropopause region and 40,000 tropospheric profiles over many cities.

Long-term measurements of stratospheric CFC12 have been conducted by the University of Frankfurt and FZ Jülich. Since 1978 they have studied the evolution of this important source gas by regular balloon soundings.

MATCH campaigns, coordinated by AWI and funded by the EU and national institutes have been carried out for more than ten successful years, most recently in the cold winter 2004/2005. These campaigns have been instrumental for our current understanding of the chemical ozone loss in the Arctic.

The Atmospheric Chemistry Department of the Max Planck Institute for Chemistry in Mainz has a research focus on ozone and the role of radicals in photo-oxidation mechanisms which play a central role in the self-cleansing capacity of the atmosphere. Computer models are developed to simulate the interactions of chemical and meteorological processes, and investigate the influences of atmospheric composition changes on climate.

The UV-group at the University of Munich investigates different influences on surface UV including modeling and detailed measurements.

QA/QC/VALIDATION

Activities towards improving the quality of balloon-ozone-soundings were continued at the World Calibration Center for Ozone Sondes (WCCOS) at FZ Jülich. In this scope, several JOSIE (Juelich Ozone Sonde Intercomparison Experiment: http://www.fz-juelich.de/icg/icg-ii/josie) sonde simulation experiments have been conducted in the laboratory to evaluate the performance of ozone sondes. In April 2004 the WMO/BESOS (Balloon Experiment on Standards for Ozone Sondes) field campaign at the University of Wyoming at Laramie, USA, was held to test the reliability of JOSIE-results in the real atmosphere. The results of JOSIE and BESOS clearly demonstrate that caution has to be exercised in making instrumental changes or in preparing/operating procedures with regard to the sonde performance and hence the interpretation of ozone trends. Under the auspices of WMO/GAW the Assessment of Standard Operating Procedures for Ozone Sondes (ASOPOS) has been initiated and a panel meeting of experts in Jülich (September 2004) critically evaluated operating procedures and is preparing a detailed document with recommendations for standardization of sonde operation.

The Regional Dobson Calibration Center for WMO RA VI Europe (RDCC-E) at the Meteorological Observatory Hohenpeissenberg (MOHp) has been responsible for second level calibration and maintenance of more than 30 operational Dobson spectrometers in Europe since 1999. The close cooperation between MOHp and the Solar and Ozone Observatory at Hradec Králové (SOO-HK, Czech Republic) guarantees excellent calibrations, training of operators, supply of the community with hard- and software. In the past 6 years 12 intercomparisons were performed with altogether 39 spectrometers from 18 countries. 9 Dobsons were completely refurbished electronically, among them 3 instruments being operated by the British Antarctic Survey at stations at the South Pole and one from Nairobi/Kenya.
The regional standard Dobson No. 064 was calibrated twice towards the primary standards (2002 at Boulder, USA, 2004 at Dahab, Egypt). During the last mentioned campaign DICE near the Red Sea the RDCC-E assisted in the organization and realization of the calibration service for the African network in WMO RA I together with the World Dobson Calibration Center (NOOA, Boulder - USA). In 2005 the staff of the RDCC-A from South Africa visited MOHp to get a training course in Dobson maintenance service.

GAWTEC, the Training and Education Center of the GAW Programme, has been established in July 2001. From the beginning, it was funded by the Bavarian State and supported by WMO. Since 2004, the German Federal Environmental Agency provides significant financial contributions to GAWTEC, which is also a co-operating partner of the German Quality Assurance/Science Activity Center. GAWTEC organizes training courses twice a year for personnel from GAW stations worldwide. It is based at the UFS Schneefernerhaus on the Zugspitze mountain. Experts from UBA, IMK at Garmisch, DWD at Hohenpeissenberg and additional invited experts hold training courses in measurement techniques of GAW-relevant parameters including ozone. Special emphasis is put on quality control, data handling and interpretation. Funding for GAWTEC will be provided at least until the end of 2006.

At the Ground Truthing Facility in Garmisch (IFU/IMK) dedicated validation studies have been performed for the instrument SCIAMACHY onboard ENVISAT by ground-based FTIR observation. Thereby significant deviations between the FTIR NO2 column amounts and the ESA SCIAMACHY results have been identified.

By IMK observations from the ground based stations in Kiruna and Tenerife have been used for validation of the SCIAMACHY and MIPAS observations on ENVISAT, and the Japanese satellite instrument ILAS-2. For the validation of MIPAS and SCIAMACHY on ENVISAT, balloon borne campaigns with a MIPAS FTIR instrument at several sites and several flights with MIPAS on the Geophysica aircraft have been performed.
INDIA

INTRODUCTION

India ratified the Vienna Convention for the protection of ozone layer on June 19, 1991 and the Montreal Protocol on Substances that Deplete the Ozone Layer on September 17, 1992. The Copenhagen, Montreal and Beijing Amendments were also ratified on 3rd March 2003. The India Country Programme was prepared in 1993 chalking out a strategy to phase-out production and consumption of Ozone Depleting Substances (ODSs).

Atmospheric ozone monitoring started in India since 1928 when Dr Royds made total ozone measurements in Kodaikanal with Dobson photoelectric ozone spectrograph as part of the first world-wide ozone measurements organized by Prof. G. M. B. Dobson. The first Dobson Spectrophotometer was acquired by India Meteorological Department (IMD) in 1940. The Indian ozone observational and research programme are as follows:

OBSERVATIONAL ACTIVITIES

Column measurements of ozone and other gases/variables relevant to ozone loss

Total ozone measurements are being carried out at 6 stations by the IMD. Present network of six Dobson and two Brewer spectrophotometers are stationed at Srinagar, New Delhi, Varanasi, Pune and Kodaikanal.

At all stations, routine measurements of total ozone are made (up to a maximum of six times per day) by trained personnel. Whenever, conditions permit, Umkehr observations are also made form these stations to compute the vertical distributions of ozone. Later, two Brewer Ozone Spectrophotometers were procured. One (#89) was installed at National Ozone Centre, IMD, New Delhi and other (#94) at Kodaikanal. It has an advantage over the Dobson Spectrophotometer because it is semiautomatic. Besides, it could also measure SO₂, NO₂ and UV-B.

Profile measurements of ozone and other gases/variables relevant to ozone loss

**Vertical Ozone Distribution**: The development of an Indian ozonesonde was taken up in 1963. The first successful sounding was carried out in September, 1964. The sondes were subsequently intercompared in WMOII03C. Further, comparisons were also held in West Germany in 1970 and 1980; in 1991 (Canada) and 1996 (Germany). Since early 1970, fortnightly soundings were attempted at New Delhi, Pune, Thiruvanathapuram, Dakshin Gangotri and Maitri (Antarctica).

**The Laser Hetrodyn System (LHS) and mm wave radiometer**: This system monitors the 10 micron ozone line in absorption mode against the Sun. The mm wave radiometer observes the 101 GHz ozone line in emission mode. This instrument has the advantage over LHS that it can be operated round the clock under all weather conditions as it does not require direct sun light. The line profiles in both the experiments are inverted to obtain the Ozone height distribution. The ozone height profiles over Delhi and Maitri have been generated for a limited period using these techniques.

**Surface Ozone Measurements**: During the 70s, the electrochemical surface ozone measurement system was successfully developed. The system is successfully operating at New Delhi, Pune, Kodaikanal, Thiruvanathapuram, Nagpur, Srinagar, Dakshin Gangotri and Maitri.

**Measurement of Minor Constituents**: Various greenhouse molecules such as Carbon Dioxide (CO₂), Methane (CH₄), Nitrous Oxide (NOₓ) have also been measured regularly at National Physical Laboratory, New Delhi, Physical Research Laboratory, Ahmedabad and Banaras Hindu University, Varanasi.
UV measurements

Broadband measurements
Regular measurement of UV-B radiation by filter photometer were started in 1979 at National Physical Laboratory, New Delhi. At present under Indian Middle Atmospheric Programme (IMAP) a chain of 7 stations have been established for routine measurement of global UV-B radiation at 280, 290, 300 and 310nm using narrow band interference filters at Shillong (IMD), Jodhpur (IMD), Pune University (Pune), Andhra University (Waltair), Mysore University (Mysore) and Trivandrum (Center for Earth Science Studies).

UV-Biometer: The measurement of Minimum Erythermal dose in the UV-B range started at Delhi in 1995 January and is continuing.

Narrowband filter instruments
India started using Narrowband filter instruments for measurement of radiation from July 1957 at 21 principal and 22 ordinary stations where continuous recording of global and defused solar radiances and bright hours of sunshine are measured. UV-A, UV-B and UV-Total measurement has also been introduced at all the stations to study the impact of climate on human health, agriculture productivity, ozone depletion etc.

Spectoradiaometers
The spectral measurements in the UV-B range at ½ nm interval started in 1989 and is continuing. The UV network is likely to expand and coordinate with international programme.

Calibration activities
The network instruments are calibrated against the National Standard at regular intervals. The National Standard is in turn, inter-compared against World standard in WMO organized International Intercomparisons. India participated in such comparisons held at Belsk (1974), Boulder (1977), Melbourne (1984) and Japan (1996). IMD, New Delhi is the National Ozone Centre for India and the Regional Ozone Centre for the Regional Association-II (Asia) of the World Meteorological Organization (WMO).

UV measuring instruments have been calibrated by using monochromators and wherever possible by using breur spectrophotometer.

RESULTS FROM OBSERVATIONS AND ANALYSIS
The major findings are as follows:

a) Analysis of long term total ozone data from the Indian stations have not shown any trend.
b) From the equator to about 20°N, the tropospheric ozone concentration remains practically same throughout the year.
c) Significant changes noticed in the vertically distribution of ozone associated with passing weather systems occur at New Delhi during the non-monsoon months.
d) Depletion of ozone over Antarctica is observed confirming occurrence of the Antarctic Ozone hole. The ozone hole phenomenon has also been observed over the Indian Antarctic station at Maitri (70°S, 11°E) where IMD monitors ozone amount throughout the year.

THEORY, MODELLING, AND OTHER RESEARCH
Impact studies of UV rays on plants, animals and human beings were conducted in Jawaharlal Nehru University, Banaras Hindu University etc. which were published in national and international journals. Central Radiation Laboratory, Pune has also been conducting radiation
studies at 45 stations. India also maintains one weather monitoring station at Maitri, Antarctica with a facility for measurements of global and diffuse solar radiation using pyranometers and of optical depth using a sunphotometer.

DISSEMINATION OF RESULTS

Results of the studies are disseminated through electronic media/website of respective institutions and query services.

Data reporting

The total ozone data and Umkehr data (vertical profile of Ozone) are being regularly sent in WMO format to the World Ozone Data Centre (WO3DC) Canada, and are being regularly published by the Centre.

Information to the public

The information on ozone concentration and other constituents are placed in the website of India Meteorological Department.

Relevant scientific papers


“UV-B flux increase during Coronal Mass Ejection” by Saumitra Mukherjee and Anita Mukherjee, Jawaharlal Nehru University, New Delhi; 4th (Virtual) Thermospheric/Lonospheric Geospheric Research (TIGER) Symposium.

“Possible Biological Effects by UV-radiation Newly Detected from Internally Administered Radioisotopes” by M. A. Padmanabha Rao, 114, Charak Sadan, Vikaspuri, New Delhi, India

“Modernization of Radiation Network” by R. D. Vashishtha & M. K. Gupta of India Meteorological Department, Pune, India

PROJECTS AND COLLABORATION

Ministry of Science and Technology, under its atmospheric programme, is developing projects for monitoring of ozone and minor constituents including various greenhouse molecules such as Carbon Dioxide (CO2), Methane (CH4), Nitrous Oxide (NOx).

Indian Middle Atmospheric Programme (IMAP), operating since 1982, has provided an umbrella for integrating all Indian efforts on ozone research. Rocket Programmes in collaboration with ex-USSR were stepped up during this period with payloads from Physical Research Laboratory, Ahmedabad and the National Physical Laboratory, Delhi. These, along with balloon and ground based measurements, have well characterized the ozonesphere over India.

Indo-Russian collaborative programme on variations in ozone and aerosol content in tropics/extratropical troposphere and stratosphere are being studied.

A collaborative programme with Ultraviolet International Research Center, Finland has been launched to monitor the UV radiations.
FUTURE PLANS

a) Continuous monitoring of ozone profile over the country.
b) Study on atmospheric chemistry in relation to ozone layer depletion and climate change.
c) To participate in the international intercomparisons of Dobson Spectrophotometer, Brewer Spectrophotometer and Ozonesonde.
d) To develop biological system to monitor UV-B.
e) To continue research on impact of UV-B on human health and eco-systems.
f) To develop climatic models to predict the climatic change over India.

NEEDS AND RECOMMENDATIONS

In accordance with the decision of the Meeting of Parties to the Vienna Convention, present activities need to be continued to monitor ozone concentration and UV radiations. Research activities relating to impact of UV radiations on life and its supporting system need to be conducted. The Ozone Research Managers meeting may recommend to the Meeting of Parties for taking decisions to request Parties to provide adequate support to continue the present activities and to carry out future plans. Developed countries may consider to have bilateral assistance programme with developing countries to strengthen ozone and UV-monitoring and research system. UNEP networking system may also include ozone and UV monitoring activities in their agenda.

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IRAN

INTRODUCTION

The meteorological organization and geophysics institute of the University of Tehran are conducting UV-B and ozone monitoring and research activities in Iran.

Generally, there is continuous cooperation and exchange of information between these centers and other research groups, such as the universities and related research institutes.

Data collection stations operating under the supervision of the above centers are listed below:

Table 1: Currently operating UV and ozone stations in I.R. Iran.

<table>
<thead>
<tr>
<th>Station Name</th>
<th>Synop Station</th>
<th>Upper Atmosphere Station</th>
<th>Surface Ozone</th>
<th>Vertical Ozone</th>
<th>Total Ozone</th>
<th>Lat.</th>
<th>Long.</th>
<th>Height (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geophysics</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>35°44'N</td>
<td>51°33'E</td>
<td>1419</td>
</tr>
<tr>
<td>Firoozkooh</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>35°43'N</td>
<td>52°34'E</td>
<td>2986</td>
</tr>
<tr>
<td>Esphalan</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>32°47'N</td>
<td>51°72'E</td>
<td>1550</td>
</tr>
</tbody>
</table>

EXISTING ACTIVITIES

Total Ozone Measurement

Esphahan ozone station is identified with an international 336 codes. Total ozone is being measured using Dobson system since January 2000.

Since April 2000, Brewer ozonometric equipment was installed and has been operating at Esphahan station.

This system measures total ozone in vertical column in an area of 1cm² by attracting solar and sky radiation. In addition, the system measures UV-B, SO₂, and NO₂.

Geophysics institute station: since 2000, total ozone is measured using Dobson system 30 minutes (from 8am to 7pm) and the result is compared with the satellite data. The data recorded at the above stations is regularity being reported to the WODC (World Ozone Data Center) and are available through the center’s web pages.

Vertical Ozone Measurement

Vertical ozone is being measured using ozonesonde, radiosonde and Balloon twice a month. The vertical ozone data recorded in the stratosphere layer (about 30Km from earth) is transmitted to the ground stations for further processing. The vertical distribution of ozone is calculated by digicora system. That combines data received from both the ozonesond (ECC/6A) and the radiosond and results in final distribution patterns of ozone.

Surface Ozone Measurement

In IRAN surface ozone outside urban area is being measured at Firooz-kooh which is an official WMO Global Atmospheric Watch (GAW). Meteorological organization also measure surface ozone in cooperation with geophysics institute of the University of Tehran in Tehran and Esphahan stations.
Upper Atmosphere Research

Espahian station identified by an OIFM code and measures on a daily basis the upper atmospheric conditions between 11 to 12 GMT every day. This measurement includes vertical pressure, temperature, humidity, wind speed and direction.

In order to study the Upper atmosphere, radiosonde (RS80) and hydrogen balloon (Totex 600gr) are used for data collection. Data recorded by these instruments then is transmitted to the global telecommunication system using a switching system.

![Figure 1: Comparison between Dobson data and satellite data for 2004.](image1)

![Figure 2: Monthly variations of total ozone for the years 2002 to 2005.](image2)
UV-B Measurement

UV-B is being measured at Esphahan station. UV is measured at spectral of 320 - 330 nm including UV-B.

Publication of Data

Total and vertical ozone data in WMO format are being regularly reported to the World Ozone Data Center in Canada (WODC). The data recorded by the stations are also being archived at the related centers.

Calibration

Data recorded by the stations is regularly checked for their validation and consistency. In the case of data inconsistency the equipment are sent to the WMO for calibration. Currently monitoring equipment at Geophysics and Esphahan stations are calibrated and properly are in operation.

However, the Firooz-kooh stations equipment are damaged and have not been in use for about 5 months.

Research Studies

Study of relation between ozone and humidity
Effects of meteorological parameters on the ozone pollution
Measurement of ozone layer changes using Dobson and Brewer photo spectrometer data.

Future Plans and Activities

Regular UV monitoring, forecasting, and public information services
Research on environmental impacts of UV increase due to the ozone depletion in different parts of country covering effects of UV radiation on
One. Human and animal health
Two. Terrestrial and aquatic ecosystems
Three. Biogeochemical cycle
Four. Air quality
Five. Materials

REQUIREMENTS

Calibration surface ozone instrument at Firooz-kooh station.
Provide and install equipment for upper atmospheric stations.
Provision of additional filters for the instruments at Esphahan station for upper atmospheric measurement
ITALY

INTRODUCTION

Italy is active in many areas of stratospheric research, including atmospheric processes, monitoring of ozone and UV levels, modeling of ozone and related species. Most of the research is performed by Universities and Italian Research Council’s (CNR) groups, but also by other institutions (i.e., ISPRA, ENEA, Air Force Meteorological Service). In the last years, these research activities have been supported by the Italian Government, Italian Space Agency (ASI), European Space Agency (ESA) and European Union.

Following the recommendations of the fifth meeting of the Ozone Research Managers, in 2003-2005, the ozone-related research has covered the traditional monitoring and archiving of measurements of tropospheric and stratospheric ozone, of other trace species and aerosols; but there was also a strong impulse to the development and implementation of new observational capabilities such as aircraft-based measurements (i.e. APE, Airborne Platform for Earth observation). Moreover, more attention has given to study the interaction between ozone and climate. The modeling activities covered the development of the algorithms for assimilating satellite data in a class of models, as well as, the full chemical and transport parameterization, and trajectory modeling, the latter has been mainly used to interpret the field data.

OBSERVATIONAL ACTIVITIES

Profile measurements of ozone

Old database

Balloon ozone soundings were performed at S. Pietro Capofiume (44.6N, 11.6E) on a weekly base from 1991 to 1997, and after that during short time campaigns. A similar activity was performed at University of L’Aquila (43.3N 13.3E) but the soundings were quite sparse on time base, from 1994 to 2002. Concerning older database, at University of L’Aquila, DIAL (Differential Absorption Lidar) ozone measurements have been also taken almost continuously from 1991 to 1996, more sparse from 1997 to 1999.

Figure 1: University of L’Aquila/CETEMPS balloon ozone soundings: ozone partial pressure vs. atmospheric pressure, in the period April 2004-April 2005. The data taken in different days are grouped per month.
Recent ozone profile monitoring

According to the commitments included in a convention between University of L’Aquila/CETEMPS (Center of Excellence for the integration of remote sensing techniques and modeling for the forecast of severe weather) and Italian Government/Ministry of Environment, from 2003, balloon ozone soundings are performed (at least 2 per months) at L’Aquila. The latter constitute the more recent and extended database of ozone profiles (see Figure 1 and Figure 2).

![Figure 1: Ozone profile data from L'Aquila.](image-url)

These data allows to figure out a good representation of the climatological behaviour of the stratospheric ozone in a geographical region centred over Italy. The ozone profile data analysis is in progress: the weather and dynamical patterns on continental scale should be considered for each observation to discriminate among the different processes affecting the evolution of the stratospheric and tropospheric ozone content.

UV and ozone column measurements

Currently, there are more than 10 UV/total ozone monitoring instruments (Brewers, pyranometers, spectrophotometers, see Table 1). The operating agencies are ISPRA, ENEA, Italian Meteorological Service, CNR, and several universities.

<table>
<thead>
<tr>
<th>Instruments</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>17 Brewer Mark IV</td>
<td>Modena</td>
</tr>
<tr>
<td>21 RB-501</td>
<td>Bolzano</td>
</tr>
<tr>
<td>22 Brewer Mark IV</td>
<td>Ispra</td>
</tr>
<tr>
<td>24 Bentham DM 150</td>
<td>Ispra</td>
</tr>
<tr>
<td>78 Brewer Mark IV</td>
<td>Rome</td>
</tr>
</tbody>
</table>

Table 1: Some of the Italian UV/total ozone monitoring instruments (Brewers, pyranometers, spectrophotometers).
Data from most of the stations are regularly sent to the central and coordinated database (e.g. WOUDC). These activities, still continuing, have been described in details in the previous report (WMO Global Ozone Research and Monitoring Project, Italian national report, Report no. 46, 2002).

In November 2003, within the cited convention between University of L’Aquila/CETEMPS and Italian Government/Ministry of Environment, two pyrometers (Yankee Environmental Systems) for UV-A and UV-B continuous monitoring were installed at L’Aquila, to be used in conjunction with the balloon ozone soundings. The UV data, as well as the ozone profiles, constitute the base for the compilation of the Italian Government annual report on ozone and UV status.

RESULTS FROM OBSERVATIONS AND ANALYSIS

The analysis of time ozone and UV components of the Italian stations (and others) have been investigated in order to single out any effective ozone trend together with the role of ozone fluctuations due to weather patterns. Many research groups adopted filtering techniques and an advanced statistical methodologies to be applied to the Dobson ozone long time series. Sensitivity studies are performed using models for the UV spectral and integrated irradiance. Most of the research groups involved in these studies have acquired enough experience so far: the main results indicate that, in spite of the unavoidable uncertainties in the input parameters (ozone, aerosol, surface albedo, pressure, temperature, relative humidity, cloud cover), measured and computed clear sky irradiances are in reasonable agreement.

THEORY, MODELING, AND OTHER RESEARCH

The modeling studies of different Italian institutions (Universities, CNR, ISPRA, etc.) concern the development and the test of 3D-atmospheric chemistry transport models with high spatial resolution, and also ozone/UV-related radiation transport modeling. At the moment, the main purpose is to understand the interplay of ozone, aerosols and greenhouse gases for a better assessment of climate effect of ozone in comparisons with that of non-reactive greenhouse gases.

The radiative forcing from ozone changes and from ozone depleting substances is significant. For this reasons the connections between ozone depletion and climate changes are strong and more complex that those simply related to CFC-control international protocols. In particular, the ozone distribution in the future will depend on the emission and impact of other greenhouse gases and not just those that deplete ozone. Scientific assessment of ozone depletion in the future can be meaningful only by coupling chemical and climate processes in numerical global models. This is the reason for including long time dependent simulations from chemistry-climate coupled models in the recent IPCC (IPCC, 2005, Special report on ozone and climate. Issues related to HFCs and PCFs) and WMO assessments. The University of L’Aquila Atmospheric modeling research group has taken part in these efforts and it is participating in the international assessment campaign (CCMVal, Eyring et al., Overview of planned coupled chemistry-climate simulations to support upcoming ozone and climate assessments, SPARC newsletter, 25, July 2005), as well as in other projects (e.g. SCOUT-O3 - EC) for the climate-chemistry numerical simulations activity.
Other activities concern the assimilation of data in global models and air mass trajectory modelling: an assimilation code has been developed into a stratospheric 3D Chemical Transport Model, and it is used for the assimilation of ozone data from ENVISAT instruments, as a support of the ENVISAT Calibration/Validation campaign. In this framework, Lagrangian trajectory modelling have been also used to analyze field and satellite data and as a support to the middle latitude and arctic APE airborne missions. Other studies, based on statistical analyses and climatological models outputs, have investigated the climatic impact of the observed antarctic ozone changes onto stratosphere and troposphere, using as input total column ozone trends.

A joint project devoted to the study of the dynamical/climatic behaviour of the antarctic ozone hole and its impact on middle latitudes, is ongoing since 2003 under the Italy/Argentina bilateral scientific programme.

DISSEMINATION OF RESULTS

Data reporting

One of the deliverable product of the Convention between University of L'Aquila/CETEMPS and Italian Government/Ministry of Environment is an annual report on the status of the ozone layer; it is mainly focused on the Italian geographical region, and should also enlighten evidences of general trends, which can have social and political consequences.

Information to the public

The activities related to the monitoring of the ozone and UV have made possible to build up the solar UV geographic patterns in Italy. The daily dose in the range 290–325nm is computed at sites where a thorough and homogeneous climatology is available. In addition, several institutions made public the estimations of the UV index. Most of them make also use, in standard radiative transfer models, of the Global Forecast System (NCEP/NOOA) for the evaluation of the ozone column and cloud coverage over several Italian sites (resolution 1x1 degrees). Some of the estimations also include the surface albedo and the terrain characteristics, others can also account for the local pollutants concentrations.

The maps of solar UV patterns for Italy meets the study requirements in the field of skin and eye epidemiology, as well as, in other investigations dealing with the impact of UV on the biosphere.

PROJECTS AND COLLABORATION

Main EU ozone-related projects (active in 2002-2005) with Italian co-partnership:
Trade-off between climate and air pollution policies, JRC research ref.2212
ENSEMBLES, IP, ref. 505539
SCOUT-O3, IP, ref. 55390

FUTURE PLANS

The traditional UV data and the ozone profile long term monitoring will constitute, in the near future, a solid database for improving the studies of the ozone-related atmospheric processes.

In addition, it is expected that with new satellite data (i.e., ENVISAT) and the growing interaction with the numerical weather forecasting community valuable advantage will be take by new and existing research facilities, also in the issues concerning the ozone-climate interactions.

Most of the information and results reported in this document has been taken from public documents and scientific papers.
**JAPAN**

In Japan, the Ministry of the Environment (MOE) and the Japan Meteorological Agency (JMA) play principal roles in monitoring atmospheric ozone, atmospheric constituents related to the depletion of the ozone layer, and surface UV-A and UV-B ultraviolet radiation. The MOE has been promoting coordination and cooperation among national institutes and universities through the Global Environment Research Fund (GERF) since 1990. The MOE also supports a programme to monitor global environmental changes on a long-term basis at the Center for Global Environmental Research (CGER) of the National Institute for Environmental Studies (NIES). The Ozone Layer Monitoring Office of the JMA coordinates observations, monitoring, and data processing of atmospheric ozone and surface UV-B radiation.

**OBSERVATIONAL ACTIVITIES**

**Column measurements of ozone and other gases/variables relevant to ozone loss**

The JMA carries out total column ozone and Umkehr measurements with Dobson spectrophotometers at three sites in Japan (Sapporo, Tsukuba, and Naha) and at Syowa Station, a site in Antarctica. Most of these measurements were initiated during the International Geophysical Year (1957–8). The JMA also began total column ozone and Umkehr measurements with a Brewer spectrophotometer at Minamitorishima (Global Atmosphere Watch, GAW, Global Station, a remote isolated island in the western North Pacific) in 1994.

The MOE observes concentrations of halocarbons (CFCs, CCl4, CH3CCl3, halons, HCFCs, and CH3Br) and HFCs at remote sites (around Wakkanai and Nemuro) and at an urban site (Kawasaki). The CGER of NIES observes halocarbons (CFCs, CCl4, CH3CCl3, and HCFCs), HFCs, surface ozone, CO2, CH4, N2O, NOx, H2, the O2/N2 ratio, and aerosols at remote sites (Hateruma and Ochiishi).

The JMA observes surface concentrations of ozone depleting substances (CFCs, CCl4, and CH3CCl3) and other constituents (surface ozone, CO2, N2O, CH4, and CO) at Ryori (GAW Regional Station in northern Japan). Concentrations of surface ozone, CO2, CH4, and CO are also observed at Minamitorishima and Yonagunijima (GAW Regional Station in the Ryukyu Islands). The JMA also observes CFCs, CO2, N2O, and CH4 in both the atmosphere and seawater of the western Pacific on board the research vessel *Ryofu Maru*.

**Profile measurements of ozone and other gases/variables relevant to ozone loss**

**Ground-based and sonde measurements**

Since October 1990, the CGER of NIES has been measuring the vertical profiles of the stratospheric ozone over Tsukuba (where NIES is located) with an ozone laser radar (ozone lidar), which is accepted as a complementary measurement by the Network for the Detection of Stratospheric Change (NDSC). Recently, the lidar data were reprocessed using a newly developed algorithm (version 2). The lidar ozone profiles were assessed by comparison with the JMA ozone sonde data and Stratospheric Aerosol and Gas Experiment II (SAGE II) ozone profiles, and were registered in the NDSC database. The CGER began measurements of vertical profiles of ozone with millimeter-wave radiometers in September 1995 at Tsukuba and in March 1999 at Rikubetsu. The JMA carries out observation of the vertical ozone distribution by KC (KI solution and carbon electrode) ozone sonde at three sites in Japan (Sapporo, Tsukuba, and Naha) and at Syowa Station, Antarctica. The KC ozone sonde is an electrochemical-type ozone sonde that has been used in Japan since it was developed by the JMA in the 1960’s. Observations are conducted once a week.
**Satellite measurements**

The Improved Limb Atmospheric Spectrometer (ILAS) and its successor ILAS-II were developed by the MOE to observe profiles of ozone and other atmospheric species related to ozone layer depletion in high-latitude regions. The ILAS was flown on the Advanced Earth Observing Satellite (ADEOS) from August 1996 to June 1997. The ILAS-II was put into space on board the ADEOS-II in December 2002 and made measurements from January to October in 2003. Data obtained with the ILAS instrument have been processed and analyzed at NIES and the version 5.2 data, which include O$_3$, HNO$_3$, H$_2$O, N$_2$O, CH$_4$, and aerosol extinction coefficients, have already been distributed to the scientific community for further research. The version 6.1 data, which include ClONO$_2$ and CFC-12 in addition to the version 5.2 species, are to be released in 2005. Data obtained with the ILAS-II instrument have been processed with the version 1.4 retrieval algorithm and are to be released to the public in 2005.

**UV measurements**

**Broadband measurements**

The CGER has been monitoring surface UV-A and UV-B radiation using broadband radiometers at 21 observation sites in Japan since 2000.

**Spectroradiometers**

The JMA observes surface UV-B radiation with Brewer spectrophotometers at Sapporo, Tsukuba, and Naha in Japan and at Syowa Station in Antarctica. The observations were started in 1990–1.

**Calibration activities**

The JMA began operation of the Quality Assurance/Science Activity Centre (QA/SAC) in Tokyo and the Regional Dobson Calibration Centre (RDCC) in Tsukuba in accordance with the GAW strategic plan 2001–7 to contribute to the assessment and improvement of the quality of ozone observations in Regional Associations II (Asia) and V (South-West Pacific) of the World Meteorological Organization (WMO). The Regional Standard Dobson instrument (D116) is calibrated against the World Standard instrument (D083) every three years. Recent intercomparison with the World Standard occurred in 2004 at NOAA/CMDL in Boulder, Colorado, USA. The Dobson instruments used for observation at domestic sites are calibrated against the Regional Standard every three years. As an activity of the RDCC, the JMA held two campaigns of Dobson Intercomparison, one in 2003 (at Tsukuba with participation from China) and the other in 2004 (at Seoul for Korea). As an activity of the QA/SAC, the JMA dispatched an expert to the Philippines to adjust the Dobson instrument and to instruct the operators in Manila.

**RESULTS FROM OBSERVATIONS AND ANALYSIS**

Continuous observation of vertical ozone profiles with a millimeter-wave radiometer in Tsukuba demonstrates that semiannual variations between 56 and 76 km are present and that the phase of the semiannual variation inverts suddenly at around 68 km. Trend analyses were done for total ozone at three sites (Sapporo, Tsukuba, and Naha) eliminating the variation component of solar activity and quasi-biennial oscillation (QBO). The results show that total ozone has decreased over the last 20 to 30 years except at Naha, which is located on a lower latitude. Trends for vertical profiles were examined by using Umkehr and ozone sonde measurements. At all sites in Japan, ozone decreases are seen in two ranges, i.e., at about 20 and 40 km altitudes.

Because spectral UV measurements by the JMA have been recorded for fewer than 15 years, the general UV trend is uncertain. However, an apparent negative relation between UV intensity and total ozone amount was found in the data collected under clear sky conditions. It was
also found that UV intensity varies depending on the weather conditions. Using the statistical relation between sunshine duration and precipitation and fine resolution weather data, an estimated UV intensity map (for every cell in a 20-km horizontal grid) was made and published for reference by the public.

THEORY, MODELLING, AND OTHER RESEARCH

A chemical climate model (CCSR/NIES CCM) based on a spectral atmospheric general circulation model (CCSR/NIES AGCM) was developed by the Centre for Climate System Research (CCSR), the University of Tokyo, and NIES and used for estimating the future development of the stratospheric ozone layer. A new version of CCSR/NIES CCM with T42 horizontal resolution has been developed that includes bromine chemistry. NIES has also developed a three-dimensional chemical transport model (CTM) in which temperature and wind velocity data are assimilated into the calculated fields in CCSR/NIES AGCM by using a nudging method. The CTM is being used to simulate the variability of ozone in the stratosphere.

The Meteorological Research Institute (MRI) of the JMA has developed a stratospheric CTM that can be run in interactive or non-interactive mode between chemistry and radiation. MRI-CTM is now operationally integrated at the JMA to produce assimilated ozone distributions by incorporating total ozone data from Total Ozone Mapping Spectrometer (TOMS) and several-day forecasts. The calculated ozone distributions are used to monitor ozone variation and for the UV forecast service. MRI-CTM is also used for research for making future predictions of the ozone layer.

The MRI, the National Institute of Information and Communications Technology (NICT), and some universities have measured O₃, HCl, HF, and other stratospheric constituents with NDSC instruments at NDSC primary stations such as Eureka (Canadian Arctic), Lauder (New Zealand), and other mid-latitude and tropical sites in cooperation with foreign research organizations.

The MRI has measured ozone, aerosols, and other species relevant to stratospheric ozone depletion using lidars and Fourier transform infrared (FTIR) spectrometers to understand the stratospheric processes over the Canadian Arctic, and it made analytical studies of ozone depletion in the Northern Hemisphere.

In spite of the short observation periods of ILAS (November 1996–June 1997) and ILAS-II (January–October 2003), their data have been used extensively to evaluate quantitatively the extent of the polar ozone destruction, for example, the determination of chemical ozone loss rates in the polar regions. Their data have also been used to elucidate the detailed chemical and physical processes related to ozone layer depletion, for example, polar stratospheric cloud (PSC) formation and denitrification mechanisms in the polar regions.

The effects of the increase in ultraviolet radiation on human health have been studied under the GERF. These studies include an exposure assessment of UV radiation, molecular epidemiological studies of UV exposure on skin cancer, epidemiological studies on ocular diseases due to increased UV radiation, and UV-B-induced immuno-suppression resulting in increases in viral infections (NIES, National Cancer Center Research Institute, National Institute of Health, National Institute of Industrial Health, Kobe University, Osaka City University, and Kagoshima University).

The effects of enhanced UV-B radiation on terrestrial plants are being studied by NIES. NIES developed a novel method of detecting plant UV-B stresses. This method is based on the detection of mRNA expression changes by cDNA macroarray analysis.
DISSEMINATION OF RESULTS

Data reporting

NIES and the Solar-Terrestrial Environment Laboratory (STEL) of Nagoya University have established stations with NDSC instruments including lidars, millimeter-wave radiometers, and FTIR spectrometers. Some of the activities conducted by these organizations have been incorporated into the NDSC complementary measurements in Japan. The reanalyzed NIES ozone lidar data were recently registered in the NDSC database, and the NIES millimeter-wave ozone data at Rikubetsu are ready for registration in the NDSC.

Observation data acquired by the JMA are submitted monthly to the World Ozone and UV Data Centre (WOUDC) in Toronto. Provisional total ozone data are also posted daily on Character Form for the Representation and Exchange of Data (CREX) of the WMO global telecommunication system (GTS), and used accordingly in the WMO Ozone Mapping Centre in Thessaloniki. In the Antarctic winter and spring seasons, total ozone and ozone sonde data acquired at the Japanese Antarctic station, Syowa, are submitted weekly to the WMO Secretariat for the preparation of Antarctic Ozone Bulletins.

Information to the public

The Annual Report on the state of the ozone layer, surface UV-B radiation, and atmospheric concentrations of ozone-depleting substances is published for the public by the MOE. Data on total ozone, ozone sonde, and UV-B measurements acquired by the JMA are summarized monthly and published for the media and the public through a website. The Annual Report of Ozone Layer Monitoring, which includes detailed trend analyses of ozone over Japan and the globe, is also published for the government and the public by the JMA. Based on UV-B observation results and newly developed ozone forecast techniques, the JMA started a UV forecast service (hourly UV-index map) through a website for the public in 2005. This service not only provides forecast information, but an analytical UV map and quasi-real-time UV observation results are posted hourly on the website.

Relevant scientific papers

The MOE supports research on global environmental changes, including ozone layer depletion, through the GERF and their results are published in the Annual Summary Reports.

PROJECTS AND COLLABORATION

Through the GERF, the MOE supports the projects “Research on explanation of long-term trend and prediction of future change of ozone layer” and “A study on elucidating mechanisms of polar ozone depletion using satellite measurement data”.

The Aerological Observatory of the JMA has developed an automated Dobson measuring system. This system reduces the operator’s burden and improves the data quality. Some foreign organizations are interested in introducing this automated Dobson system. The JMA is ready to provide technical support, and plans for collaboration with various organizations are now in preparation.

FUTURE PLANS

The NIES millimeter-wave radiometers, which have been used for the continuous measurement of the vertical profile of ozone over Japan, have been improved to extend the altitude range of the observation. It is planned to measure continuously the vertical profiles of ozone from the lower stratosphere to the mesosphere as an NDSC activity.
The calibration of Dobson instruments from all over the world to the World Standard is essential to precisely monitor global ozone change. However, most Dobson instruments in Asian countries, except in China, Korea, and Japan, have not been calibrated since 1996. The JMA is now planning to hold a Dobson Intercomparison with the participation of four countries in the spring of 2006.

The observation of ozone, water vapour, and other species will be performed near the tropical tropopause to understand the role of the tropical transition layer. Developing and improving the numerical models, CCM and CTM, will continue, which will enable better prediction of future changes of the ozone layer and better understanding of the mechanisms of the chemistry–climate interaction.

Studies using ILAS and ILAS-II data will be continued to better understand the mechanisms of polar ozone destruction.

**NEEDS AND RECOMMENDATIONS**

To evaluate the changing state of the ozone layer and ground-level UV radiation, including detection of ozone layer recovery, systematic observations with the cooperation of international monitoring networks, such as the NDSC and the WMO GAW Programme, should be continued. To detect recovery of the ozone layer, a fine and high-quality ozone-monitoring network is required. However, some regions do not have a well-functioning systematic calibration system. Each government that conducts ozone observation should recognize the importance of periodic Dobson Intercomparisons that ensure high-quality ozone data, and promote activities relevant to the detection of ozone recovery.

To more precisely predict future changes in the ozone layer, numerical models need to be improved; especially desirable is integration between stratospheric and climate models. The interactions between climate change and ozone layer depletion and changes in the ozone layer in the post-CFC period due to the emissions of CH₄, H₂, and N₂O need to be assessed. Chemical and dynamical processes including the formation of PSCs and denitrification mechanisms, cross-tropopause transport, and the ozone budget near the tropopause region need to be studied.

The effects of increased UV radiation on human health and ecosystems need to be studied, especially the effects of possible longer exposure to increased UV radiation under rising temperature conditions.

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KRYGYZSTAN

Influence of Stratospheric Aerosol on General Contents of Atmospheric Ozone over Central Asia

INTRODUCTION

At present conclusive evidences of the aerosol influence on variability of ozone exist, in particular, on observations of ozone contents after powerful volcanic eruptions (Krekov M.M., Zvenigorodskiy S.G., 1990). Herewith the intercoupling between ozone and aerosol, as indicated in (Ivlev L.S., Chelibanov V.P., 2001), it is enough complex and ambiguous. Four types of interdependences are given here: 1) ozone present in atmosphere enhances generating of aerosol particles, 2) aerosol particles, in particular, dust ones, promote ozone molecules destruction, 3) the processes take place in atmosphere, which ozone simultaneously change the contents of the aerosols and ozone and 4) the aerosols influence on ozone contents in atmosphere through radiation processes.

The issue of dependencies between aerosol content and ozone has become particularly sharp in connection with a problem of the ozone holes. Thus, it is worth to note that this problem is far from ambiguous solution. So, repeatedly observed considerable reductions of the ozone contents in the layers, polluted by aerosol, can be called both by direct decay of the ozone molecule on the dust particles, and by other processes (Ivlev L.S., Chelibanov V.P., 2001).

The volcanic eruptions can influence on general contents of ozone (GCO) in atmosphere moreover mechanisms of this influence can be the most different. For instance, in nonvulcanic periods to account of presence in atmosphere dioxide sulphurs $\text{SO}_2$ (the sulphureous gas) can occur the accumulation of ozone under photooxidation $\text{SO}_2$ by oxygen of the air (Ivlev L.S., Sirota V.G., Khvorostovsky S.N., 1990) may intervene.

Below we shall examine some mechanisms of the accumulation and exhaustions of the stratospheric ozone under influence of sulphuric-acid aerosol under different conditions of the atmosphere.

METHODOLOGY

In Central Asia region measurements of vertical structure of concentration and optical characteristics of stratosphere and troposphere aerosol have been conducted since 1988 at the Lidar Station Teplokluchenka (Kyrgyz Republic) by means lidar method. The high mountain Lidar Station Teplokluchenka (LST) is located on a height over 2000 m above sea level southeast of a high mountain lake Issyk-Kul in Central Tien-Shan ($42.5^\circ$ N, $78.4^\circ$ E).

The main questions of methodology multiwavelength lidar sensing of the atmospheric aerosol, processing backscattering signal and receptions optical and microphysical characteristics of the aerosol in (Chen et al., 2002; Chen et al., 2004) are stated.

In Figure 1 monitoring data of aerosol backscattering coefficient for 1988-2001 are given. For more than 20 years the monitoring of $\text{O}_3$, $\text{CO}_2$, $\text{H}_2\text{O}$, $\text{NO}_2$ and spectral transparency of the atmosphere (STA) in the central part of Euro-Asian continent is made only at the Issyk-Kul station ($42.6^\circ$ N, $77^\circ$ E, 1650 m a.s.l.) located at the bank of Issyk-Kul Lake in the mountains of northern Tien-Shan (Kashin, et al., 2000; Semyonov, et al., 2000).

The measurements of total ozone column ($X$) are performed with the help of a spectrophotometric scanning set (SPS).
Figure 1: Monitoring data of integral backscattering coefficient in the height range 15-30 km.

Mean monthly X values in the atmosphere over the central part of Eurasia for 1979 – 2001 in Figure 2 are given (Toktomyshev and Semenov, 2001).

Figure 2: Total ozone content (X) in an atmosphere of the Northern Tien Shan.

THE BACKGROUND PERIOD

The set up in (Chen and Lelevkin, 2000) heights of the location of the backscattering ratio maximum $R_{\text{max}}$ over the Central Asian region (the average height of 18.25 km, 17.62 in cool and 19.0 km in warm half-year) indicate that maximum of concentrations of the background stratospheric aerosol (SA) is mainly formed in the stratosphere itself during a year regardless of a season. Consequently, in the background periods the sulphurous gas SO$_2$ arrival from the troposphere is not a direct source of the aerosol formation. Carbonsulphide, photodissociated with the sulphureous gas forming in the lower stratosphere, seems to play the main role in the background SA shaping.

The results of the experiment show (Chen and Lelevkin, 2000), that prior to the Volcano Pinatubo eruption in the background period the area of 24–29 km is marked out with local minimums in the correlations function where the main mass of the background aerosol is concentrated. This happens at the height of the ozone concentration maximum (24–27 km), not in the field of Junge aerosol layer, that allows to expect that the ozone accumulation takes place here, i.e. O$_3$ generation under photooxidation of SO$_2$ by the air oxygen (Ivlev L.S., Sirota V.G., Khvorostovsky S.N., 1990): $3\text{SO}_2(^3B_1) + O_2 \rightarrow \text{SO}_3 + O(^3P)$.
In winter (December) in stratosphere of moderate latitudes prevails a zonal (western) circulation. In January and February the circulation in stratosphere is unstable, the meridional transference prevails against the zonal one (Stolypina, 1981). It is because the circumpolar cyclonic whirlwind shifts to the south and the Pacific maximum – to the north, and both of them become immobile. Increase in height of SA maximum location and in maximum optical thickness is observed (Chen and Lelevkin, 2000).

VOLCANIC SULFUR DIOXIDE AND OZONE

Pinatubo volcano eruption (Philippines), June 15-16, 1991 was one of the most powerful in this century. As a result of the eruption a huge amount of substance in a gaseous and aerosol phase was thrown out in atmosphere. Evaluations, carried out because of satellite observations have shown, that the mass of a thrown out sulfur dioxide makes approximately 20 million tons (Bluth G.J.S. et al., 1992); that has rendered a powerful influence to radiating processes in atmosphere as well as to transformation of ozone layer. Oxidation of sulphureous gas leads to formation of fine dispersion sylph-acid aerosol.

In Figure 1 it is visible, that the concentration of SA arises sharply during 3 months, reaching its maximum value in January 1992 and than it decreases up to May. Increase of an optical thickness in an initial phase is explained by that to poor absorbed sylph-acid aerosol the diameter of particles dispersion increases fast.

The condition of the SA and its parameters variations had greatly influenced both the radiative processes and the ozone layer transformation.

In summer the SA transformation at altitudes lower than 20 km is caused by western air masses transference. In the higher stratosphere at eastern circulation the conditions promoting aerosol’s transference from tropical latitudes into moderate zones of the northern hemisphere are absent. In summer the meridional circulation in stratosphere weakens practically up to zero (Stolypina, 1981). The aerosol appeared at the heights more than 20 km was registered in the late October of 1991 at establishing western circulation of a moderate zone of stratosphere. For all of this, the summer stratospheric anti-cyclone was destructed and new favorable conditions for aerosol transference from tropical zone into the moderate ones of the northern hemisphere in upper stratosphere appeared. During this period one observed an increased SA maximum (Chen and Lelevkin, 2000).

From June 1992 to January 1993 the SA grew in tens time in comparison with the background ones before the volcano eruption (Chen and Lelevkin, 2000). Then, the concentration of AS had gradually come back to the level of 1988-1989. It was connected to that that at volcanic eruptions of the explosive type not only sulfate particles of different sizes appeared in stratosphere, but great amount of the sulfur dioxide (Turko et al., 1983) too. The thickness of the SA increased after coming of sulfur dioxide in stratosphere due to its consequent oxidation up to sulfuric acid vapors which were condensed together with a water vapor on the already available in stratosphere particles, or form new particles by homogenous nucleation from a gas phase. In our case study these processes evidently continued up to the end of 1992 – beginning of 1993.

The outcomes of measurements have shown (Chen and Lelevkin, 2000), that major masses of volcanic aerosol in the first period after the volcano eruption are located in layers of 16-18 and 23-25 km. During the next period after the particles’ sedimentation the formation of the aerosol from sulfur dioxide in a layer of maximum stratospheric ozone concentration of 26-28 km occurs.

Therefore, the reduction of total ozone occurs (see Fig. 3), which seems to be used up in the photooxidation reaction \( \text{SO}_2 \) (Ivlev L.S., Sirota V.G., Khvorostovsky S.N., 1990):

\[
3 \text{SO}_2(3B_1) + O_3 \rightarrow \text{SO}_3 + O_2.
\]

Since June 1992 till February 1993 a sharp deceleration of the aerosol concentration depletion is observed. In the result of this reaction the stratospheric aerosol
has been formed during this period: $SO_3 + H_2O \rightarrow H_2SO_4$. During the period of March-August 1993 the SA concentration diminished nearly by two times and total ozone sharply proliferated (Fig. 3) as a result of ozone generation under SO$_2$ photooxidation by the air oxygen:

$$3SO_2 \left( ^3B_1 \right) + O_2 \rightarrow SO_3 + O \left( ^3P \right)$$ (Okabe, 1981).

Figure 3: Joint distribution of $R_{max}$ and total ozone (1 – total ozone, 2 – $R_{max}$).

**EMPIRICAL LINKS BETWEEN THE SA AND GENERAL CONCENTRATION OF OZONE**

The analysis of empirical links between the SA and general concentration of ozone (GCO) has shown that during all operating period of the volcano Pinatubo eruption the coefficient of the linear correlation between SA and GCO appeared equal to $r=0.87 \pm 0.07$, when the reliability of the linear correlation was $P=0.99$.

During the background period before the volcano eruption the SA was formed in stratosphere due to photo-oxidation of stratospheric SO$_2$, and a coefficient of correlation between the SA and GSO was negative ($r=-0.46 \pm 0.17$ with $P=0.95$). When the products of the volcano eruption came in our latitudes at a stage of forming the SA from SO$_2$ (from June 1993 to February 1993) the O$_3$ was absorbed in a sulfate aerosol, and the concentration of O$_3$ reduced. Thus the negative correlation between SA and GCO increased in comparison with the background period: $r=-0.76 \pm 0.12$, $P=0.99$.

During the ozone generation at photo-oxidation of the sulfur dioxide by oxygen of the air, occurred from March 1993 to August 1993, the coefficient of correlation became positive again: $r=0.88 \pm 0.07$, $P=0.99$.

**CONCLUSION**

Thereby, the process of SA relaxation after the volcanic eruptions is accompanied by its double impact influencing the stratospheric ozone content: by reducing general concentration of ozone at reaction of SO$_2$ photo-oxidation, and by increasing GCO as a result of the ozone generation at SO$_2$ photo-oxidation by oxygen of the air. Hence, alongside with the given reasons (Toktomeshev and Semenov, 2001) of the appeared over Central Asia of so-called "local ozone
holes" (ozone concentration reduction), there are other mechanisms of the ozone reduction, set out above, connected with the ozone absorption by the stratospheric sulfate aerosol and connected with sulfur dioxide photo-oxidation, being during the background period in stratosphere.

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LITHUANIA

Network

Lithuanian Hydrometeorological Service under the Ministry of Environment (LHMS) follows the standard programme of observations of the World Meteorological Organization recommendable for hydrometeorological services. The state of ozone layer is monitored at the Kaunas meteorological station (WMO Index 312). Total ozone measurements have been carried out with the M -124 filter ozonometer since 1 January 1993. The Kaunas station is located close to the centre of Lithuania.

Ultraviolet solar radiation measurements have been carried out at Kaunas and Palanga (by the Baltic Sea) since 2000. Mean and maximum daily radiation is monitored using the UV-Biometers type 501 A, version 3 (in Kaunas – UV-A and UV-B, in Palanga – UV-B).

Instrument calibration

The M -124 filter ozonometer is calibrated every two years at the Remote Sensing Scientific Research Centre of the Main Geophysical Observatory in St Petersburg, Russia. The last calibration was carried out in 2004.

The UV-Biometers have been calibrated by the LHMS Metrological Laboratory in 2005. Local standard meters were re-calibrated with a higher-class standard instrument in 2002 and should be re-calibrated again in 2006.

Results from observations and data analysis

All observational data are stored and processed on a regular basis. Due to comparatively short series of observations, they are considered insufficient for a comprehensive study. In 2001, the LHMS Climatology and Methodology Division (lead researcher – Dr Audronė Galvonaitė) completed a study titled “Ozone In the World and In Lithuania”. In 2003, the LHMS Meteorology Division carried out the ozone data analysis resulting in establishment of the mean total ozone values for the period of 1993 – 2002 that have since been used to assess the ozone layer depletion over Lithuania. It is also used in monitoring the ozone column and assessment of its quantitative changes. In case of significant ozone layer depletion, the LHMS Meteorology Division originates warnings disseminated through the mass media and over the Internet.

Since 2001, the LHMS Meteorology Division has been originating the UV index forecasts (UVI) for annual periods of May – August. These forecasts are disseminated through the mass media and Internet. In case of significant ozone layer depletion, the Division originates warnings communicated through the mass media and Internet.

Since 2002, the total ozone values and their change as well as the ultraviolet solar radiation intensity figures are published in the State of the Environment annual reports issued by the Ministry of Environment of the Republic of Lithuania.
In 2004, the total amount of atmospheric ozone fluctuated quite significantly. As in previous years, its minimum value (about 300 DU) was observed in autumn, and the maximum (about 400 DU) – by the end of winter and in spring. In 2004, the absolute minimum amount of atmospheric ozone (247 DU) was measured in November, while its absolute maximum (497 DU) – in March. Mean annual amount of the total ozone was 351 DU. Comparing with 2003 measurements; the total amount of atmospheric ozone remained practically the same.

International cooperation

The ozone measurement data are sent on a regular basis to the World Ozone and Ultraviolet Data Centre (WOUDC) in Toronto, Canada. Since 2004, also the UVB measurement data from the Kaunas station have been sent to WOUDC.

Establishment of the UV monitoring network in Lithuania was supported by the Italian – Lithuanian Counterpart Fund. The Polish Institute of Meteorology and Water Management assisted LHMS in application of the UV Index forecasting model.
Future

Observations of the ozone layer and the UV radiation will be continued. Though our current ozone meters are of good quality, however, we would like to increase the precision of measurements provided we could obtain a Brewer Spectrophotometer. It is a modern and highly precise instrument used worldwide since 1980-ties. Besides the direct measurements, it can be used as a standard meter for calibration of the UV-Biometers. Its purchase and installation will form a good basis for the further acquisition of the ozone and ultraviolet information and its scientific and practical applications.

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MALAYSIA

OBSERVATIONAL ACTIVITIES

The International Conference on Tropical Ozone and Atmospheric Change held in Penang, Malaysia in February 1991 underscore the lack of atmospheric ozone measurements and research in the equatorial region. Realizing the importance of developing countries in the tropics to play a more important role in the global initiatives to achieve a better understanding of the atmospheric changes and the effects on the environment linked to ozone changes, Malaysia has initiated its active involvement in the World Meteorological Organization (WMO) Global Ozone Observing System (GO3OS) with the launching of its ozone monitoring programme in October 1992.

The ozone monitoring programme involves monitoring of ozone concentrations at the surface, the vertical distribution of ozone up to the stratosphere and total column ozone in the atmosphere.

Column Measurement of Ozone

Total column ozone measurements in Malaysia began in 1992 using the Sci Tec Inc. Brewer Ozone Spectrophotometer Mark II, instrument number 090 at the Petaling Jaya Station, Petaling Jaya Meteorological Station (Lat. 03 deg.06’ N, Long. 101 deg. 39’ E, elevation 45.7m above MSL). This is the only regular long term total column ozone monitoring site in Malaysia.

Ultraviolet Measurements

Daily ultraviolet radiation measurements are also made using the same Brewer Spectrophotometer mentioned above.

Ozone Profile Measurements

Ozone profile measurements are conducted at the Kuala Lumpur International Airport, Sepang Meteorological Station (Lat. 2 deg. 43’ N, Long. 101 deg. 42’ E, elevation 16.3m above MSL) using the Vaisala Digicora system. Sounding are made twice a month during the times when the AURA satellite passes the station. Overpass times are made available by the SHADOZ (Southern Hemisphere ADditional OZonesondes) project.

Surface Ozone

Hourly surface ozone concentration is measured continuously using the Thermo Environment Instruments Inc. C49 Ozone Analyzer at the Cameron Highlands Meteorological Station (Lat. 04 deg. 28’ N, Long. 101 deg. 22’ E, elevation 1545.0m above MSL). Prior to that, surface ozone measurements were made using the Monitor Lab ML 9811 Ozone Analyzer from the year 1997 to 2002.

Calibration Activities

The Brewer Spectrophotometer is calibrated by International Ozone Services of Canada. The calibration is performed every two years. Quality assurance and quality control procedures are strictly adhere to during ozone sounding and surface ozone measurements.
RESULTS FROM OBSERVATIONS AND ANALYSIS

Total Column Ozone

The time series of total column ozone measurements since 1992 is shown in Figure 1.

Figure 1: Total Column Ozone 1992-2005
Petaling Jaya

Ozone Profile Measurements

The figure below shows the latest vertical ozone profile made available on the SHADOZ website.
RESEARCH ACTIVITIES

Asian Ozone Pollution in Eurasian Perspective

This project concerns spatial distribution and temporal variability of ozone, an important atmospheric constituent in the troposphere, which is an effective greenhouse gas and a toxic substance for human health and vegetation. It aims to get a perspective of surface ozone in Asia and to discuss how it is affected by human activity by clarifying both intra- and inter-continental long-range transport over the Eurasian continent.

The project compiles observational data of surface ozone at remote and rural sites as well as selected urban sites data in Asia. The integrated dataset will illustrates the overview of ozone pollution in Asia, and will be used to evaluate the contribution of emissions of ozone precursors in various parts of Asia as well as those from Europe and North America by using the "tagged" method of the global chemical-transport. International workshops are organized for the discussion of data compilation/ analysis and for proposing policy strategy how to reduce ozone pollution in Asia.

DISSEMINATION OF RESULTS

Data Reporting

Total column ozone data and vertical ozone profile data are reported every six months to the WMO Global Atmosphere Watch World Ozone and Ultraviolet Radiation Data Centre in Canada.

Information to the Public

Vertical ozone profile data is made available after every launch on the SHADOZ website for the scientific community.

Daily solar UV index is posted on the Malaysian Meteorological Department's website as a service to the public.

Annual air quality reports containing data and information on ozone monitoring is published annually.

Information on ozone and ozone issues are discussed and posted on the Malaysian Meteorological Department website.

Relevant Scientific Papers


Effects of monsoons and ENSO on atmospheric ozone in Malaysia, Jurnal Fizik Malaysia, Volume 22, Number 1 & 2, March & June 2002. Authors: J T Lim, S F Lim, C P Leong, H Tsuruta, S Yunemura.
PROJECTS AND COLLABORATION

Southern Hemisphere Additional Ozone Sondes (SHADOZ)

SHADOZ (Southern Hemisphere ADditional OZonesondes) project is designed to remedy data discrepancy of a number of stations that are operating in the southern hemisphere tropics and subtropics which has differing frequency and reporting procedures. SHADOZ achieve its aims by coordinating launches, supplying additional sondes in some cases, and by providing a central archive location. Data will be collected in a timely manner and will be available through this website to the SHADOZ and TOMS Science Teams, as well as to the scientific community as a whole.

Currently, twelve active sites are participating in SHADOZ. The sites are at Ascension Island; American Samoa; Fiji; Irene, South Africa; Java, Indonesia; Malindi and Nairobi, Kenya; Natal, Brazil; Paramaribo, Surinam; La Réunion, France; San Cristóbal, Galapagos; and Kuala Lumpur, Malaysia.

FUTURE PLANS

Air Quality Modelling

The Malaysian Meteorological Department (MMD) in its 5-year Development Plan beginning in 2006 plans to introduce air quality forecasting as one of its product and service. Among the parameters that will determine air quality will be surface ozone concentrations in ambient air.

Monitoring

The MMD is planning to measure surface ozone concentrations at the Danum Valley GAW Station to detect changes in ozone levels during the dry biomass burning season in the island of Borneo.

Research

A proposal to study the oxidant and particle photochemical processes above a South-East Asian tropical rain forest prepared by the Lancaster University, United Kingdom is being evaluated by funding agencies. This joint project involves a number of parties including the MMD.

NEEDS AND RECOMMENDATIONS

Capacity building and exchange programmes and twinning projects in quality assurance and quality control is needed to improve data quality and accuracy.

Increase in the frequency of ozonesonde launch from once a fortnight to once a week. The SHADOZ project is expected to provide this support.

Total column ozone and UV measurements to cover the island of Borneo. An additional Brewer spectrophotometer installed in the state of Sabah will provide these data over Borneo.

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MOROCCO

INTRODUCTION

Casablanca is the biggest city in Morocco. It’s located at 7.7° West and 33.6° North. Its climate is soft.

Casablanca is a city which has evolved very quickly, its automobile park represents almost 50% of the national park and its industry represents 60% of the whole national industrial activity. The number of inhabitants in Casablanca is now about 4 millions. But each day, there is many cars and trucks which enter to Casablanca and many individuals who come to the city, from other small cities, for their work. This situation, with others, made of Casablanca a locality very polluted. Obviously, this pollution can affect the measurement accuracy.

Casablanca is also a coastal city and breeze is a mechanism which attenuate the pollution concentration in the city.

In Casablanca, the Ozone measurement began on 1969. Until now, three instruments have been used for that purpose: Dobson (1969-1989); Brewer MKII (1989-1993); Brewer MKIII (2000-…). Unfortunately, all over this period, no calibration test has been done.

MEASUREMENTS

Dobson period (1969-1989)

With this instrument, measurements have been done during the zenith period, once per day. But, during the weekends and days off and days with an important cloud cover, measurements didn’t have been done.

Brewer MKII period (1989-1993)

During this period, measurements have been performed during two hours (12-14 o'clock), because the instrument is automatic. Probably measurements are more accurate at least if the instrument is well calibrated. The measurements have been performed as above.

Brewer MKIII period (2001-…);

This period began on late 2000. The instrument measures the SO₂ concentration and the UV radiation also. The measurements are continuous and it’s an easy to use instrument. Obviously it keeps the same limitations as its ancestor.

MISSING DATA AND DATA QUALITY

The missing data reflect the instruments availability and, in the sense explained above, the operating mode. These lacks are numerous in Casablanca during the winter season. There is many months indeed where no data has been recorded.

Data quality reflects the instrument calibration. In this respect, some data are abnormally low or abnormally high. As examples, data for February 1977 and October and November 1979 ozone layer thickness reached, respectively, 210, 221 and 230 DU, and during February 1973 it reached 425. Web distributed maps, show that, during these periods, data are almost normal; Thus, unless these data represent a local phenomenon which had not been observed by satellite and other terrestrial observing systems, it can be considered as, at least, suspect.
Evolution of the Annual Ozone Layer to the Vertical of Casablanca

The annual Ozone layer thickness to the vertical of Casablanca, has two characteristics; The first is its general decay and the other is its bimodal shape. These two characteristics are made evident by the two trends put in the figure below. The other things that one has to mention are the years with missing data (1986-1988) and years with brewer instrument (1989-1983) which are separated from the other with the blue vertical bar in the figure below.

Seasonal Evolution of Ozone Layer to the Vertical of Casablanca

In general, Spring is the season where ozone is at the highest level and autumn is the season where it is at its lowest level. There is, however, some years where winter is the lowest level. These years coincide with the years mentioned above as years with some suspect data in winter months. The bimodal shape is visible also in these curves.
Annual Rhythm of the Monthly Evolution of the Ozone Layer to the Vertical of Casablanca

The annual rhythm, month by month, shown in the figure below, shows that there is an increase in the ozone layer between October and May and a decrease between May and September.
UV Radiations

The Brewer MK III measures also the UV radiations; The figure below, presents the monthly evolution of ozone and the UV radiation during the year 2001. The UV radiation's curve is similar to direct radiation, i.e., it increases during the summer and decreases during the winter. What is curious is the positive correlation between the ozone and the UV radiation.

Conclusion

As a conclusion, there is a long period of record of ozone in Casablanca. These records have some suspect data, but when monthly or annual averages are considered, the data show some consistent shapes with other localities. The decrease observed is also consistent with decreases observed elsewhere.

In the research center there is many trial-studies to evaluate the impact of weather parameters on health, but we never tried to use ozone layer thickness as a predictor because records aren't continuous or don't coincide with clinical data.

Other activities related to Ozone

Each year, since the creation of the annual anniversary of the ozone layer, the Moroccan meteorological Service participate to the radio programmes in order to promote the public awareness of the environmental effects of the emissions of controlled substances and other substances that deplete the ozone layer.

Other activities related to the industrial sector will be also presented.
NETHERLANDS

Observations at KNMI in De Bilt, Netherlands, (52.10N, 5.18E)

Brewer MKIII Spectrophotometer:
- Total ozone, continuous observations since 1994.
- Data deposited at WO3UDC.
- Near-real-time data “WMO Ozone Mapping Centre” and WO3UDC
- UV scans, about once per hour since 1994.
- Data deposited at EDUCE database
- Aerosol optical depth (experimental product)

Research and applications
- Validation of ozonesonde and satellite observations
- Radiative transfer model studies
- UV exposure estimations by RIVM
- Calibration of UV-index forecasts
- Algorithm development for global UV index forecast

Ozonesondes
- Profiles of ozone, temperature, humidity and wind, typically up to ~30 km.
- Approx. weekly balloon releases since 1992.
- Intensified releases during MATCH campaigns.
- Extra releases for ENVISAT / AURA validation.
- Data deposited at WO3UDC.
- Data deposited near-real-time at NILU database.

Research and applications:
- Stratosphere/troposphere exchange
- Validation of satellite observations (GOME and SCIAMACHY)
- Development of GOME/SCIAMACHY ozone profile retrieval.
- Near-real-time data “WMO Ozone Mapping Centre” and WO3UDC

Observations at the Suriname Meteorological Service (MDS) in Paramaribo, Suriname, (5.81N, 55.21W).

Brewer MKIII Spectrophotometer:
- Continuous total ozone and UV scans, plus Umkehr at dusk and dawn: since April 1999.
- Data deposited at NDSC, WO3UDC databases
- Near-real-time data “WMO Ozone Mapping Centre” and WO3UDC

Research and applications
- Validation of ozonesonde and satellite observations
- Radiative transfer model studies
- Calibration of UV-index forecasts
- Algorithm development for global UV index forecast

Ozonesondes:
- Profiles of ozone, temperature, humidity and wind, typically up to ~30 km.
- Weekly balloon releases since September 1999.
- Data deposited at SHADOZ (Southern Hemisphere Additional Ozone Sondes) and NDSC databases
- Data deposited near-real-time at NILU database.
Research and applications:
- Atmospheric transport, dynamics and chemistry in the Tropics
- Stratosphere/troposphere and inter hemispheric exchange
- Validation of satellite observations (GOME and SCIAMACHY)
- Development of GOME/SCIAMACHY total ozone and ozone profile retrieval.
- Algorithm development for global UV index forecast

Projects relating to satellite observations

- The EU/ESA project “PROMOTE” (PROtocol MO nitoring for the GMES Service Element) [http://www.gse-promote.org/]
  - Coordinator of the project
  - Service provider for Ozone
  - Service provider for Ultra-violet radiation
  - Service provider for Air quality
  - Service provider for Climate Change
- The ESA project TEMIS (Tropospheric Emission Monitoring Internet Service) [http://www.temis.nl/]
  - Coordinator of the project
  - Ozone: Tropospheric and Stratospheric
  - Nitrogen dioxide: Tropospheric and Stratospheric
  - Ultra-violet radiation: UV-index and dose
  - Ozone profile (under development)
  - Aerosol absorbing index (under development)
- ENVISAT validation
  - Coordinator of the project
  - Validation of various ENVISAT products
- Preparation of future satellite missions:
  - Preparation for operational missions: GOME-2 (Ozone SAF) and Sentinels 4/5 (GMES)
  - KNMI is leading the TRAQ (TRopospheric and Air Quality) proposal in response to ESA Call for next Earth Explorer Missions of 15 March 2005. Collaboration between KNMI, CNRS/CNES/LMPAA, and SRON.
  - Participate in designing future ESA atmospheric chemistry research missions: GeoTROPE, and PREMIER.
  - Potential contribution to ESA sentinels 4 and 5 for monitoring atmospheric chemistry (CAPACITY project)

Ozone Monitoring Instrument (OMI)

KNMI is the principal investigator institute of the Ozone Monitoring Instrument (OMI) and responsible for operating and the in-flight calibration of the instrument and together with NASA and FMI for delivering data products (algorithm development & data processing) and performing their validation.

- OMI contributions:
  - Monitoring of the ozone layer: Continues the TOMS, SBUV and GOME ozone column and profile data. In addition OMI will continue the GOME column measurements of BrO, OCIO and NO₂
  - Air quality: Observe tropospheric pollution and its precursors due to biomass burning, industrial and traffic emissions such as NO₂, aerosols, SO₂, formaldehyde and ozone. The
small pixel size (13 km x 24 km at nadir) is the highest spatial resolution ever achieved from space for these trace gas measurements and increases sensitivity in the troposphere

- Climate change: Continues the TOMS, SBUV and GOME total ozone record. Provide a record of tropospheric ozone and UV absorbing aerosols

- OMI measurements:
  - OMI data products are: Total column amounts of ozone, NO$_2$, BrO, OClO, SO$_2$, formaldehyde, tropospheric column amounts of ozone and NO$_2$; profile information for ozone; aerosol optical depth, aerosol single scattering albedo and in addition surface UV-B radiation, cloud top pressure and cloud coverage
  - OMI was launched in July 2004 and will operate till 2009/2010
  - First OMI total ozone data for the long term arctic ozone trend was delivered for the IPCC/TEAP Special Report: Safeguarding the ozone layer and the global climate system: Issues related to the hydrofluorocarbons and perfluorocarbons, Summary for Policy Makers, WMO/UNEP, 2005
  - The OMI total ozone column was publicly released in May 2005
  - Most OMI products will be publicly released mid 2006
  - Most OMI products are available with daily global coverage with a (nadir) footprint of 13 km x 24 km
  - The total ozone, NO$_2$, and volcanic SO$_2$ column and tropospheric NO$_2$ column will be delivered within 3 hours of observations with global coverage as of early 2006 for use in numerical weather forecast and air quality models as well as volcanic warnings applications for air craft traffic

**Modelling**

Chemistry-transport modelling:
- Tropospheric ozone budget.
- Effects of aviation
- Aerosols
- Lightning and surface NOx
- Stratospheric ozone
- Methane

Dynamics:
- Stratosphere/troposphere coupling
- Age of stratospheric air
- Antarctic sudden stratospheric warming
- Stratosphere as predictor of the troposphere
- Tropical tropopause layer

Validation:
- Ozone soundings in De Bilt and Paramaribo
- Participation in ENVISAT validation

**Assimilation of ground-based and satellite observations:**
- EU project GOA: data assimilation of GOME ozone and GOME NO$_2$
- TEMIS: Tropospheric Emission Monitoring Internet service, [http://www.temis.nl](http://www.temis.nl)
- EU-project ASSET: Assimilation of Envisat data, see [http://darc.nerc.ac.uk/asset/](http://darc.nerc.ac.uk/asset/)

**Contribution to Assessment reports:**
- IPCC Assessment – Fourth Assessment Report (4AR)
- WMO/UNEP Ozone Assessment Report 2002
NEW ZEALAND

OBSERVATIONAL ACTIVITIES

In New Zealand, most ozone and UV related research is undertaken by the National Institute of Water and Atmospheric Research (NIWA), a Crown Research Institute (CRI), at research centres at Lauder and Wellington. The site at Lauder is the southern hemisphere mid-latitude charter site in the Network for Detection of Stratospheric Change (NDSC). Several other CRIs have programmes to monitor changes in biologically damaging UV radiation (e.g., Industrial Research, LandCare, AgResearch), some of which are conducted in collaboration with NIWA. The Physics and Astronomy Department at the University of Canterbury also contributes to ozone related research while the Department of Preventive and Social Medicine at the University of Otago researches epidemiological aspects of excess UV radiation exposure. This research is funded primarily through the Foundation for Research Science and Technology (FRST), but with considerable funding coming from international contracts and also from commercial activities such as providing research products and instrument development.

Column measurements of ozone and other gases/variables relevant to ozone loss

*Dobson Spectrophotometer* Ozone measurements were made using a Dobson spectrophotometer (no. 17) located at Invercargill (46.4°S, 168.3°E) from 3 July 1970 to 30 September 1987. The instrument was then re-located to Arrival Heights in Antarctica (77.8°S, 166.7°E), another NDSC site, where it has been operated since. Another Dobson spectrophotometer (no. 72) has been operated at NIWA Lauder (45.0°S, 169.7°E, alt 370m) since the beginning of 1987 in collaboration with NOAA. A satellite measurement based climatology of total column ozone differences between Lauder and Invercargill has been used to geographically shift the Invercargill measurements to Lauder (Figure 1). The large downward step in ozone during the mid-1980s, which occurred throughout the southern mid-latitudes, remains unexplained. The Dobson spectrophotometers are also used to make Umkehr observations to estimate the vertical profile of ozone in the stratosphere.

*UV-visible spectrometers* UV-visible spectrometers at Arrival Heights, Macquarie Island (54.5°S, 159.0°E), Lauder, Mauna Loa (19.5°N, 155.6°W), Tarawa (1.5°N, 173°E), and Kiruna (67.8°N, 21.1°E) measure total column ozone. These spectrometers are also used to measure slant column NO2 over Kiruna, Japan, Hawaii, Tarawa, Lauder, Macquarie Island and Arrival Heights, BrO over Kiruna, Lauder and Arrival Heights, and OCIO over Kiruna and Arrival Heights.

*FTIR* High resolution Fourier transform infrared (FTIR) interferometers at Lauder and Arrival Heights are used to determine column amounts of O3, HCl, HNO3, CH4, N2O, HF, COF2, CO, C2H6, ClONO2, CFC-11, CFC-12, NO2, OCS, and CO2. For some of these species, 2 to 4 vertical partial column amounts can also be retrieved from the FTIR spectra.

![Figure 1: Annual mean total column ozone at Lauder from the combined Lauder and Invercargill Dobson spectrophotometer measurements.](image)
Profile measurements of ozone and other gases/variables relevant to ozone loss

**Ozonesondes** Vertical ozone profiles over Lauder have been measured weekly since August 1986 using ECC ozonesondes. Until 1996 flights were made twice weekly during the last four months of the year, a time when remnants of the Antarctic ozone hole may be advected over New Zealand. The flights are made to an average altitude of \( \sim 33 \) km. A summary of the data from these flights is presented in Figure 2.

**Microwave radiometer** A microwave radiometer has been used to make daily measurements of ozone profiles at Lauder since November 1992 over the altitude range 20-70 km. A second instrument is used to make water vapour profile measurements in the upper stratosphere and lower mesosphere. A microwave radiometer is also operated at Arrival Heights for monitoring the ClO vertical profile.

**Ozone lidar** In collaboration with RIVM, The Netherlands, vertical ozone profiles measurements have been made using a UV DIAL system since November 1994 over the altitude range 8-50 km.

**Frost point hygrometer flights** In a new collaborative effort with NOAA/CMDL, frost point hygrometer flights have been made from Lauder every second week since August 2004 to measure stratospheric water vapour. The programme is co-funded by the NOAA GCOS office.

**Surface ozone measurements**

Surface ozone measurements have been continuously monitored at Lauder since December 2003. Measurements are made with a TEI in-situ spectrophotometer. Similar measurements have been made at Arrival Heights since December 1996. These measurements were made with a Dasibi in-situ spectrophotometer until it was replaced with a TEI monitor in December 2003.

**UV measurements**

**Spectroradiometers** Since late 1990, surface spectral UV irradiance has been measured routinely at Lauder. Scans are made at 5 degree steps in solar zenith angle, and at 15 minute intervals over the midday period. The spectral resolution is 0.6-0.8 nm, and data cover the range 285 to 450 nm in 0.2 nm steps. Similar spectral measurements have been undertaken in collaboration with NOAA/CMDL at two sites in the USA (Mauna Loa Observatory, Hawaii, and Boulder, Colorado); with the Australian Bureau of Meteorology at three sites in Australia (Melbourne, Alice Springs and Darwin); and with the University of Tokyo at one site in Japan using weatherproof, temperature-controlled spectrometers. In addition to the measurements of spectral irradiance, measurements of actinic fluxes, more relevant for atmospheric chemistry, are now available from Lauder and Tokyo.

**Broadband measurements** The spectral measurements are complemented by a wide range of broadband measurements and by all-sky images taken at 1 minute intervals to quantify the effect of cloud distribution and type on UV radiation. Broadband instruments which measure integrated
UV with a response close to the erythemal action spectrum, are operated by NIWA at several sites in New Zealand (Invercargill, Lauder, Leigh, Paraparaumu, Christchurch) and in the Pacific (Cook Islands – Rarotonga and, Fiji). Because of mismatch between instrument sensitivity and erythemal response, corrections which depend on solar elevation and ozone are applied to these broadband instruments.

Dosimeter badges for measuring personal exposures of UV have been developed in collaboration with the University of Canterbury. Similar sensors have been used in UV displays which have been deployed in public places and outdoor sporting events.

**Narrowband filter instruments** Since late 2002, the US Department of Agriculture have been undertaking complementary measurements of UV radiation at Lauder using multi-filter rotating shadow band radiometers. This provides a direct linkage between the UV climatologies of New Zealand and the USA.

**Calibration activities**

The Lauder Dobson spectrophotometer was last calibrated in a Dobson intercomparison at Lauder in November and December 2001, which included the world standard instrument no. 83. The next intercomparison will occur in January 2006 in Melbourne. The Arrival Heights Dobson spectrophotometer was intercompared against the world standard in Melbourne in early 2004.

An intercomparison of vertical ozone and temperature profile measurements, the TOPAL (Temperature and Ozone Profiler Assessment at Lauder) campaign, was conducted from 8-20 April 2002 and included measurements from ozonesondes, the RIVM ozone lidar, a NASA/GSFC ozone lidar and the microwave radiometer.

The NIWA UV spectrometers represent the state-of-the-art, and have participated with distinction at an international intercomparison campaign in the USA, and have been used to certify instruments for acceptance by the Network for Detection of Stratospheric Change. During a measurement campaign at Lauder, the NIWA spectrometers were cross calibrated against a European reference instrument that measured spectral radiances as well as irradiances.

**RESULTS FROM OBSERVATIONS AND ANALYSIS**

**The NIWA assimilated total column ozone data base**

The NIWA assimilated total column ozone data base combines satellite-based measurements of total column ozone from 4 Total Ozone Mapping Spectrometer (TOMS) instruments, 4 Solar Backscatter Ultra-Violet (SBUV) instruments, and three different retrievals from the Global Ozone Monitoring Experiment (GOME), and compares these against ground-based measurements made by the global network of Dobson spectrometers to create a homogeneous data base that combines the advantages of global satellite measurements with the advantages of the stability of ground-based measurements. This data base was used extensively in the WMO/UNEP ozone assessment in 2002 and is planned for use in the next ozone assessment in 2006. The use of this data base to track the long-term evolution of the Antarctic ozone hole is shown in Figure 3.

**Analysis of UV measurements**

Data from NIWA UV spectrometers have been used to identify problems with satellite-derived UV and have led to improvements in retrieval algorithms. Studies have quantified the effects of clouds on UV at Lauder and at sites in Antarctica. A detailed intercomparison between calculated and measured UV for clear skies at several sites has identified deficiencies in the aerosol parameters which are used as inputs to the model. The same analysis quantified errors due to a recently-discovered temperature-dependence in PTFE, which is the material used in the diffusers of the spectrometers. Instruments and retrieval algorithms have now been improved to
properly take these into account. Studies have identified the importance of the altitude distribution of ozone and temperature in modulating UV radiation received at the surface. We have also shown that while UV intensities are relatively high in the New Zealand summer, they are relatively low in the New Zealand winter, and this has serious implications for human health (contributing to skin damage in summer, and vitamin-D deficiency in winter). A study has quantified the increased UV exposure experienced during skiing.

Trend analysis
Regression analysis models have been developed to quantify trends in ozone and the trace gases affecting ozone.

Detection of the peak in stratospheric chlorine loading

Measurements of HCl and ClONO$_2$ at Lauder can be used to monitor stratospheric chlorine loading, which appears to have reached a peak in the mid-1990s but not to have significantly decreased since then.

THEORY, MODELLING, AND OTHER RESEARCH

The Dilution Effect

The effect on mid-latitude ozone of the mixing of ozone depleted air from within the Antarctic vortex over southern mid-latitudes following the breakup of the vortex has been quantified for 1998, 1999, and 2000 by calculating the trajectories of ensembles of ozone-depleted air parcels. The results suggest that dilution of the ozone hole is the major source of summertime southern mid-latitude ozone loss, amounting to as much as 4-5% of the total ozone even after allowing for photochemical recovery. This is the first time the large-scale dilution has been quantified. This work was done in collaboration with the University of Canterbury.

Chemistry-climate modelling

Since 2001 NIWA has been operating a coupled chemistry-climate model (CCM) to investigate the feedbacks of stratospheric change on climate change, and the effects of climate change on the ozone layer. This work has been undertaken in close collaboration with the UK Met Office and with the NOAA Geophysical Fluid Dynamics Laboratory. The Unified Model with Eulerian Transport And Chemistry (UMETRAC) is run on NIWA’s cray T3E supercomputer. This modelling programme will contribute to the SPARC (Stratospheric Processes And their Role in Climate) initiated activity to conduct an internationally coordinated validation of CCMs.

Use of satellite data

Data from satellite programmes of the USA, European and Japanese space agencies have been used in ozone and UV related research in New Zealand. In turn we have contributed to a number of satellite measurement validation activities. Total column ozone measurements from a variety of instruments have been used to generate an assimilated total column ozone data base (see Section 2.1). Ozone profile measurements from the SAGE II, POAM II and POAM III instruments have been used to diagnose ozone loss rates over Antarctica.
UV effect studies

Scientists from NIWA and the University of Otago have been working in close collaboration to understand the factors affecting excess UV exposure in New Zealand schoolchildren. Over the summer of 2004/2005 UV exposure of 491 school children at 28 schools over 14 one-week periods were measured and combined with data from activity diaries maintained by the children and data from questionnaires to create a data base that can be used to answer many questions related to UV exposure of school children. For each participating child, the UV exposure over a one week period was logged using electronic UV monitors specifically developed for this project. The monitors were programmed to log UV exposure at 8-second intervals throughout the day. The resultant data base is now been analyzed to quantify the most important factors affecting UV exposure in schoolchildren. This work was co-funded by NIWA and the Cancer Society of New Zealand.

DISSEMINATION OF RESULTS

Data reporting

Measurements from the following sites are regularly submitted to the NDSC data base: From Lauder: ozonesonde and lidar ozone profiles, Dobson spectrophotometer O₃, NO₂ columns, UV weighted irradiances (Erythema, UVA, UVB), vertical columns of HCl and HNO₃; from Arrival Heights: vertical columns of HCl and HNO₃, Dobson spectrophotometer O₃, NO₂ columns; from Kiruna: NO₂ columns; from Moshiri (Japan): NO₂ columns; from Boulder (USA): UV weighted irradiances (Erythema, UVA, UVB); from Mauna Loa Observatory (Hawaii): NO₂ columns, UV weighted irradiances (Erythema, UVA, UVB); from Macquarie Island (Australia): NO₂ columns.

Measurements from the following sites are regularly submitted the WOUDC data base: From Lauder: Ozonesonde ozone profiles; from Arrival Heights: Dobson spectrophotometer O₃.

Aerosol Measurements from Lauder are regularly submitted to the BSRN data base.

Information to the public

Data from NIWA’s broadband instruments and radiative transfer calculations are used to provide the public with information on UV radiation levels via the Internet. Data are also provided to the public via the Cancer Society of New Zealand’s web pages, and via contracts with New Zealand Met Service.

FUTURE PLANS

The International Polar Year (IPY)

New Zealand researchers are included on a number of IPY proposals, including proposals on air-ice chemical interactions (AICE) and ultraviolet radiation in polar environments. The eventual extent of New Zealand participation in these programmes will depend on how much IPY targeted funding will be made available through New Zealand funding agencies.

NEEDS AND RECOMMENDATIONS

The following needs and recommendations require attention:

- The contribution of very short-lived compounds to stratospheric species abundances, and in particular BrO, needs to be better quantified.
- The inability of state-of-the-art atmospheric chemistry models to reproduce the inter-hemispheric differences in the response of ozone to the Mt. Pinatubo volcanic eruption suggests that our knowledge of the aerosol chemistry driving ozone changes is incomplete.
• We need better quantification of how management of banks of ozone depleting substances may affect the recovery of the global ozone layer.

• In depth assessment of when and where the ozone layer is likely to recover is required. Is any observation of the onset of recovery observed to date consistent with our best understanding of atmospheric chemistry and dynamics? The importance of attribution in the analysis of ozone recovery must be stressed.

• The effects of stratospheric change on surface climate change, and the mechanisms involved, need to be better quantified. In particular forcing of the southern annular mode through Antarctic ozone depletion, and its effect on southern middle and high latitude surface climate, needs to be better understood.

• A better understanding of the drivers of southern hemisphere mid-latitude ozone changes is required. Current models are unable to reproduce changes in southern mid-latitude ozone observed over the past 25 years.

• We need to confirm that ground- and satellite-based measurements of bromine and chlorine containing compounds are in agreement and that the stratospheric loading of these trace gases is consistent with our understanding of their surface source emissions.

• Working with health sciences to improve our understanding of both the positive and negative effects of UV exposure.

RELEVANT SCIENTIFIC PAPERS

A list of selected key scientific papers from New Zealand ozone and UV research over the past 3 years, is provided below:


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NIGERIA

INTRODUCTION

Environmental problems emanating from ozone depletion and other sources have always been of great concern to the government and people of Nigeria. As the regional and global atmospheric pollution problems continue to assume a wider dimension, putting a high population at risk and seriously threatening the ecosystems, various programmes have been embarked upon in Nigeria to address these problems. Succeeding governments have implemented existing policies on environmental issues and formulated new ones in line with global programmes designed for the achievement of a friendly and sustainable environment. This commitment to environmental issues by the government led to the signing and ratification of the Montreal Protocol on substances that deplete the ozone layer by Nigeria on the 31st of October, 1988.

Monitoring and research on ozone, UV radiation and related atmospheric constituents are carried out by different institutions in Nigeria. The aim is to support government policies on environment and thereby contribute positively to the implementation of the Vienna Convention for the protection of the ozone layer and its Montreal Protocol, as well as the United Nations Conference on Environment and Development in 1992 which emphasized the need for global understanding and proposed corrective actions in several areas of global environmental change, among them the effects from changes in the ozone layer. The increasing involvement of these institutions has greatly enhanced the development of the national programme on ozone monitoring and research in Nigeria.

MONITORING OF GAW PARAMETERS:

The monitoring of total column ozone and other atmospheric constituents under the auspices of Global Atmosphere Watch (GAW) programme of WMO started in Nigeria in 1993 with the establishment of a GAW station each in Lagos (Latitude06°36’N; Longitude 03°26’E; Elevation 10m) and Oshogbo (Lat.07o 47’N; Long.04o 29’E; Elevation 304.5m) by the Nigerian Meteorological Agency (NIMET) which was then known as Department of Meteorological Services in the Ministry of Aviation.

Total Column Ozone

The GAW station in Lagos measures total column ozone and it is the only such station in Nigeria. Subject to the state of the atmosphere, daily routine measurements up to a maximum of ten observations are made with the Dobson spectrophotometer #5703 (Shimatzu type). Total ozone measurements are archived in the database of NIMET in Lagos.

Other GAW and Related Parameters

When the Oshogbo GAW station was established in 1993, a number of parameters were being measured as shown in table 1. However, due to factors which include non-regular calibration of the instruments, non availability of spare parts and essential consumables, some of these parameters are not being measured currently. Efforts are being made to resuscitate the station for effective operation under the expansion of GAW programme by NIMET.
It is expected that in the near future the range of UV index measurements across the country would be evaluated and that could form a basis for developing a programme on early warning system for the general public on UV-B exposures in Nigeria.

Air Quality/Air Pollution Monitoring:

A number of institutions are engaged in the monitoring and research needed to improve the understanding of ozone issue and other trace gases in Nigeria. For instance, the Obafemi Awolowo University (OAU) set up an automatic air quality monitoring station in Lagos in 1991. The station measures trace gases mixing values including surface ozone at 10 metres height. Also, the Atmospheric Research and Information Analysis Laboratory (ARIAL) of the Centre for Energy and Development of the same university has recently engaged in the assessment of available satellite data for stratospheric and tropospheric ozone over Nigeria. This is intended to be used to provide the trends and spatial resolutions forecast of these parameters over Nigeria. NIMET collaborates with OAU and some other institutions on issues relating to the protection of the ozone layer, impact of UV-B on human health and the environment in general.

Calibration/Intercomparison

Our Dobson spectrophotometer is calibrated (mercury lamp and standard lamp tests) every month and the calibration data are documented. The instrument has also successfully participated in two international intercomparisons organized by WMO for all the Dobson instruments operated in Africa. These took place in Pretoria, South Africa in 2000 and Dahab in Egypt in 2004.

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**Table 1: Parameters measured at GAW station, Oshogbo.**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Instrument</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Ozone</td>
<td>UV-Photometric Ozone Analyzer</td>
</tr>
<tr>
<td>Aerosols</td>
<td>Improved module aerosol sampler</td>
</tr>
<tr>
<td>UV_B Radiation</td>
<td>Kipp &amp; Zonen Pyranometer</td>
</tr>
<tr>
<td>Total Radiation</td>
<td>LI-COR Silicon Pyranometer</td>
</tr>
<tr>
<td>Diffuse Radiation</td>
<td>Kipp &amp; Zonen Pyranometer</td>
</tr>
<tr>
<td>Incident Radiation</td>
<td>Kipp &amp; Zonen Pyranometer</td>
</tr>
<tr>
<td>Net Radiation</td>
<td>PH Schenk Net Radiation Sensor</td>
</tr>
<tr>
<td>Atm. Turbidity</td>
<td>Mainz 11 Noll Sun Photometer</td>
</tr>
<tr>
<td>Precipitation Sample</td>
<td>Aerochem Metric ppt. collector</td>
</tr>
</tbody>
</table>
TRENDS IN TOTAL OZONE AND SURFACE OZONE

Figure 1: shows trend in total ozone in Lagos from 1993 – 2004, while Figures 2-5 show surface ozone on selected days at Oshogbo.

ONGOING STUDIES AND RESEARCH INTERESTS

Total column ozone and UV-B radiation observations by NIMET are not yet sufficient for comprehensive studies. However, a number of studies are being carried out using available data. These include:

- Diurnal variation of total ozone in Lagos
- Relationship between total ozone and some meteorological variables in Lagos
- Seasonal variation of total ozone over equatorial belt
- Influence of stratospheric ozone on local weather
- UV-B trends in Nigeria
- UV-B daily forecast in Nigeria
- Effects of UV-B on human health and ecosystems.

Recent Papers

Various investigations are at different stages. However, some presentations have been made at conferences, symposia, seminars and workshops in recent times. They include:
• Meteorology and Air Pollution Monitoring in Nigeria, Presentation, Conf. on Air Quality Monitoring and Management, 2002.

DISSEMINATION OF RESULTS

Submission of data to WOUDC

Total ozone data measured in Lagos are transmitted monthly to the World Ozone and Ultra-Violet Data Centre (WOUDC) in Toronto, Canada. As at the time of preparation of this report, the latest total ozone data from Nigeria in WOUDC are for the month of June, 2005.

Public Awareness Campaign on Ozone Issue:

In Nigeria, priority attention is given to public awareness campaign on the consequences of a depleted ozone layer. Various activities are regularly organized by NIMET to sensitize the general public on the need to protect the ozone layer. Since 1997, NIMET has been observing the International Day for the Preservation of the Ozone Layer on the 16th of September each year. Activities during such occasions in the past included press release by the Director-General/Chief Executive Officer of NIMET on the state of ozone in Nigeria and the Global Update of the Ozone Layer, public lectures on ozone in relation to the health, socio-economic and industrial sectors, poster sessions on ozone issue, quiz competitions among secondary school students on ozone and the environment, etc. Policy makers, industrialists, scientists, students, the press and the grassroots are usually involved in activities. Indeed the awareness programme is yielding the desired results in Nigeria. The series of lectures on ozone day in the past will be published and made available to the public during this year’s ozone day observation. Titles of past public lectures on ozone day are stated below:

• Can man rebuild the ozone layer he destroyed in order to save the earth?, 1999 Osaghaede, S.E.
• Public awareness on ozone issue for the benefit of man, 2000, Osaghaede, S.E. and Muyiolu, S.K.
• The ozone issue and socio-economic life: the past, present and future, 2001, Nnodu, I.D.
• Is ozone monitoring and research beneficial to man? 2003, Obioh, I.B.
• Extending lives of humans, animals and plants through ozone monitoring, 2004, Abu, A.

IMPLEMENTATION OF THE MONTREAL PROTOCOL

It is pertinent to state here that since Nigeria signed and ratified the Montreal Protocol on substances that deplete the ozone layer, the government has taken a number of actions towards the protection of the ozone layer and the environment in general. Some of these actions include:

• Control of environmentally harmful substances such as CFCs and Halons known to deplete the ozone layer
• In the refrigeration and air-conditioning sectors, old technologies are being replaced with state-of-the-art ozone-friendly alternatives as part of efforts to implement the phase-out of Ozone Depleting Substances (ODS).
• Banning of importation of used refrigerators and freezers.
FUTURE MONITORING AND RESEARCH PLANS:

There is a deliberate plan by the government of Nigeria to continue to encourage and carry out monitoring and research that will improve the understanding of ozone issue and thereby contribute positively to the regional and global efforts towards the protection of the ozone layer and sustainability of the environment. The Nigerian Meteorological Agency is spearheading this course and with adequate funding by local and international organizations, the agency will vigorously pursue the following programmes:

- Continuation of Total Ozone and UV-B radiation measurements.
- Increase in network of GAW stations for the monitoring of total ozone, surface ozone, greenhouse gases, UV-B radiation, solar radiation, acid rain, etc.
- Measurement of ozone profile with Dobson spectrophotometer and other methods.
- Daily UV-B radiation forecast for Nigeria.
- Effects of increased UV-B on human and animal health, as well as the ecosystems.
- Continuation of awareness campaign on ozone and related issues.
- Increased collaboration with local and international organizations on ozone and related issues.

NEEDS AND RECOMMENDATIONS

In order to facilitate the ongoing and planned ozone, UV radiation monitoring and research programmes in Nigeria, assistance will be needed in the following areas:

- Expansion of total column ozone measurements. This will involve among other things, acquisition of Brewer spectrophotometer and other modern instruments.
- Acquisition of instruments for ozone profile measurement.
- Expansion of our UV-B and solar radiation monitoring network.
- Regular calibration of instruments especially in the developing countries to ensure high quality data for research and other purposes.
- Training of personnel to enhance professional competence in monitoring, data processing and research especially in the developing countries.
- Provision of spare parts and essential consumables.

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Ozone monitoring and related research in Norway involves several institutions and there is no distinct separation between research and development, monitoring and quality control. The following significant research and monitoring activities have been carried out in Norway since 2002.

**OBSERVATIONAL ACTIVITIES**

The Norwegian Pollution Control Authority established the programme “Monitoring of the atmospheric ozone layer” in 1990, which at that time only included measurements of total ozone. The Norwegian UV network was established in 1994/95 and consists of eight 5-channel GUV instruments located at sites between 58°N and 79°N. In addition, the observational activities include ozone lidar and ozonesonde measurements. Table 1 gives an overview of the location of the various stations, the type of measurements, and the institutions responsible for the daily operation of the instruments at the different sites.

<table>
<thead>
<tr>
<th>Station</th>
<th>UV</th>
<th>Total ozone</th>
<th>Ozone profiles</th>
<th>Institute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landvik, Grimstad, 58°N</td>
<td></td>
<td></td>
<td>x</td>
<td>Norwegian Radiation Protection Authority</td>
</tr>
<tr>
<td>Blindern, Oslo, 60°N</td>
<td>x</td>
<td></td>
<td></td>
<td>University of Oslo/ Norwegian Institute for Air Research</td>
</tr>
<tr>
<td>Østerås, Bærum, 60°N</td>
<td>x</td>
<td></td>
<td></td>
<td>Norwegian Radiation Protection Authority</td>
</tr>
<tr>
<td>Bergen, 60°N</td>
<td>x</td>
<td></td>
<td></td>
<td>Norwegian Radiation Protection Authority</td>
</tr>
<tr>
<td>Kise, Mjøsa, 60°N</td>
<td>x</td>
<td></td>
<td></td>
<td>Norwegian Radiation Protection Authority</td>
</tr>
<tr>
<td>Trondheim, 63°N</td>
<td>x</td>
<td></td>
<td></td>
<td>Norwegian Radiation Protection Authority</td>
</tr>
<tr>
<td>Ørlandet, 63°N</td>
<td>x</td>
<td></td>
<td></td>
<td>Norwegian Institute for Air Research</td>
</tr>
<tr>
<td>Andøya, 69°N</td>
<td>x</td>
<td>x</td>
<td></td>
<td>Norwegian Institute for Air Research /Andøya Rocket Range/ FFI*</td>
</tr>
<tr>
<td>Ny-Ålesund, 79°N</td>
<td></td>
<td></td>
<td>x</td>
<td>Norwegian Institute for Air Research</td>
</tr>
</tbody>
</table>

* Norwegian Defence Research Establishment

**Column measurements of ozone and other gases relevant to ozone loss**

Total ozone measurements using the Dobson spectrophotometer were performed on a regular basis in Oslo from 1978 to 1998 and in Tromsø from 1985 to 1999. Brewer measurements were started up in Tromsø in 1994, but after the termination of ozone-related observations at the Auroral Observatory in Tromsø in 1999 the instrument was moved to Andøya, 130 km southwest of Tromsø. Daily total ozone values for Oslo and Andøya are now based on measurements with Brewer spectrometers. The ozone values are based on direct-sun measurements, when available. However, on overcast days and days where the solar zenith angle is large the ozone values are based on the global irradiance method. As the Arctic Lidar Observatory for Middle Atmosphere Research (ALOMAR), which has replaced Tromsø as the North Norwegian ozone and UV monitoring site, is located north of the polar circle (69.3°N, 16.0°E, [http://alomar.rocketrange.no/](http://alomar.rocketrange.no/)), there are no measurements of total ozone for about 100 days due to the polar night.

The Norwegian Institute for Air Research (NILU) is also operating instruments capable of monitoring ozone relevant traces gases at two sites. At ALOMAR two UV/VIS DOAS instruments (SYMOCS) are measuring total columns of ozone, NO₂, BrO and OClO since the late 1990s. Additionally, there is a DOAS instrument (type SAOZ) at Ny-Ålesund, measuring total columns of ozone and NO₂ since 1991. The NO₂ and ozone measurements at ALOMAR fulfil the requirements of the Network for the Detection of Stratospheric Change (NDSC) and formal approval is expected in autumn 2005. The SAOZ measurements contribute to the NDSC.

**Profile measurements of ozone and other parameters relevant to ozone loss**

Norway operates one ozone lidar, which is located at the ALOMAR facility at Andøya. Together with the Norwegian Defence Research Establishment and the Andøya Rocket Range, NILU has operated the ozone lidar continuously since January 1995. Since 1997 the instrument
has been approved as a complementary site of the NDSC, and data are submitted to the NDSC database. The ozone lidar has also been used to measure polar stratospheric clouds and stratospheric temperature profiles. The lidar is run on a routine basis during clear sky situations providing ozone profiles in the height range 8 to 50 km. The latest measured raw data profiles and the latest analysed ozone data are available at http://alomar.rocketrange.no/alomar-lidar.html.

NILU has operated an ozonesonde station at Ørlandet (63.4°N, 9.2°E) since 1994 and is nominally launching between 1 and 4 sondes per month, depending on the time of the year. These measurements have traditionally been used for national monitoring purposes. In addition, NILU has participated in a number of experimental (match) campaigns where several stations launch sondes in a coordinated pattern to probe the same air masses several times. This is used to estimate ozone loss as a function of time and sun-lit hours. Finally, the ozone vertical profile soundings have extensively been used for validation of satellite instruments, especially on the ERS-2 and Envisat platforms.

UV measurements

**Narrowband filter instruments**

The instruments in the Norwegian UV network are designed to measure UV irradiances in 4 channels. Using a technique developed by Dahlback (1996), we are able to derive from the raw data total ozone abundance, cloud cover information, complete spectra from 290 to 400 nm, and biologically weighted UV doses for any action spectrum in the UV.

In November 2004, NILU installed a NILU-UV radiometer at the new Norwegian research station, Troll, in Antarctica. The instrument was brought back to Norway in March 2005 to participate in the intercomparison of multiband filter radiometers (MBFR) at NILU (the FARIN campaign described in section 5). The NILU-UV instrument will be reinstalled at the Troll station in November 2005 and will be calibrated every year against a travelling standard. The NILU-UV measurements at the Troll station will be traceable to the Norwegian UV network through yearly calibration of the reference instrument at the Norwegian Radiation Protection Authority.

**Spectroradiometers**

Spectral UV irradiances (both direct and global scans) are measured daily with Brewer instruments at Department of Physics, University of Oslo and at ALOMAR.

There have also been campaigns with global spectral measurements in the wavelength range from 290-450 and collection of data from periods in 2001, 2002, and 2003. In 2005 there were campaigns with direct and diffuse spectral measurements

**Calibration activities**

**The Brewer instruments**

The Brewer instrument at the University of Oslo has been in operation since summer 1990, while Brewer operations in North Norway started in 1994. The International Ozone Services, Canada, calibrates the Brewer instruments in Oslo and Andøya on a yearly basis, and the instrument are regularly calibrated against standard lamps in order to check their stability. The calibrations show that the Brewer instruments have been stable during the 11 years of observations. The total ozone measurements from the Oslo Brewer instrument agree well with the Dobson measurements.

The GUV instruments

The Norwegian FARIN project, described in section 5, included a major international UV instrument intercomparison. All in all 51 UV radiometers from various nations participated, among them 39 multiband filter radiometers (MBFR’s). The instruments were also characterized on site. Beside measurements of spectral responses, measurements against QTH lamps and of the cosine responses were done for a selection of instruments. The data are available on the ftp server zardoz.nilu.no at NILU. The directories are /nadir/projects/other/farin/rawdata and /nadir/projects/other/farin/processed.

RESULTS FROM OBSERVATIONS AND ANALYSIS

Ozone observations in Oslo

In order to look at possible ozone reductions and trends for the period 1979 to 2004 in Oslo we have employed the total ozone values from 1979 to 1998 from the Dobson instrument, whereas for the period 1999 to 2004 the Brewer measurements have been used. The results of the trend analysis are summarized in Table 1. For spring months a significant negative trend of –0.35% per year is observed. For the winter, summer and fall months no significant trends are detected. When all months are included a significant negative trend of –0.17% per year is observed. The analysis of the data shows that the low ozone values in the 1990’s contribute strongly to the observed negative trends in total ozone. For 2004 the yearly mean ozone value was 0.4% higher than the long-term yearly mean.

Table 1: Percentage changes in total ozone per year for Oslo for the period 1.1.1979 to 31.12.2004. The numbers in parenthesis gives the uncertainty (1σ).

<table>
<thead>
<tr>
<th>Time period</th>
<th>Trend (% per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter: December – February</td>
<td>-0.11 (0.11)</td>
</tr>
<tr>
<td>Spring: March – May</td>
<td>-0.35 (0.11)</td>
</tr>
<tr>
<td>Summer: June - August</td>
<td>-0.02 (0.06)</td>
</tr>
<tr>
<td>Fall: September - November</td>
<td>-0.10 (0.06)</td>
</tr>
<tr>
<td>Annual</td>
<td>-0.17 (0.05)</td>
</tr>
</tbody>
</table>

Ozone observations at Andøya

As mentioned, ozone measurements in North-Norway were performed in Tromsø until 1999 and at ALOMAR/Andøya from 2000. Correlation studies have shown that the ozone climatology is very similar at the two locations so that the two datasets are considered as equivalent representing one site. For the time period 1979 – 1994 total ozone values from the satellite instrument TOMS (Total ozone Mapping Spectrometer) were used because of insufficient calibration of the Tromsø Dobson instrument before 1991 and low data coverage (after 1990, there is a good agreement between TOMS and Tromsø Dobson and Brewer measurements). The result of the trend analysis is summarized in Table 2. No significant trends were observed for Andøya for this time period. The missing trend in spring is mainly caused by several warm winters since 1998 with very high total ozone, compensating the significant negative trend before 1998.

Table 2: Percentage changes in total ozone per year for Andøya/Tromsø for the period 1979 to 2004. The numbers in parenthesis gives the uncertainty (1σ).

<table>
<thead>
<tr>
<th>Time period</th>
<th>Trend (% per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring: March – May</td>
<td>-0.13 (0.12)</td>
</tr>
<tr>
<td>Summer: June - August</td>
<td>-0.00 (0.05)</td>
</tr>
<tr>
<td>Annual (March-September)</td>
<td>-0.08 (0.06)</td>
</tr>
</tbody>
</table>

In recent years, the historical total ozone series from Tromsø (Fery spectrograph: 1935-1939, Dobson #14: 1939-1972, 1985-1999) and Svalbard (1950-1962) have been re-analyzed, homogenized, and evaluated by multi-linear regression methods (Hansen and Svenøe, 2005). The analysis, based on a combination with TOMS data, revealed a strong influence of the local stratospheric temperature at the 30 mbar level and a composite influence of climate tele-

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connection patterns. Variations in the recent decades are best explained if the linear trend since 1978 is modified, such that in years with a weak polar stratospheric vortex the trend is set to zero.

A preliminary analysis of the Svalbard data reveals similarities with the Tromsø results but also some surprising differences, like the importance of the QBO and the solar cycle in summer.

Measurements with the ALOMAR ozone lidar were used, in combination with leading chemical transport models, to quantify Arctic ozone loss during several winters in the late 1990s (Hansen et al., 1997; Hansen and Chipperfield, 1999). They were also used to study other properties of the Arctic ozone layer, like laminae and summer variability (e.g., Orsolini et al., 1997; Orsolini et al., 2003) and properties of polar stratospheric clouds (PSCs) were investigated for the winters 1995/96 and 1996/97 (Hansen and Hoppe, 1997; Deshler et al., 2000).

**UV observations**

<table>
<thead>
<tr>
<th>Year</th>
<th>Oslo</th>
<th>Andøya</th>
<th>Tromsø*</th>
<th>Ny-Ålesund</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>387.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1996</td>
<td>387.4</td>
<td>253.6</td>
<td>218.5</td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td>415.0</td>
<td>267.0</td>
<td>206.5</td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td>321.5</td>
<td>248.4</td>
<td>217.7</td>
<td></td>
</tr>
<tr>
<td>1999</td>
<td>370.5</td>
<td>228.0</td>
<td>186.1</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>363.0</td>
<td>239.7</td>
<td>231.0</td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>371.0</td>
<td>237.0</td>
<td>208.6</td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td>382.5</td>
<td>260.0</td>
<td>201.8</td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td>373.2</td>
<td>243.4</td>
<td>No</td>
<td>measurements</td>
</tr>
<tr>
<td>2004</td>
<td>373.2</td>
<td>243.7</td>
<td>190.5</td>
<td></td>
</tr>
</tbody>
</table>

*The GUV instrument at Andøya was operating at Tromsø in the period 1996 – 1999

**THEORY, MODELLING, AND OTHER RESEARCH**

**University of Oslo**

**Department of Geosciences** The model primarily used for studying the stratospheric ozone layer is called Oslo CTM2 and it is a global three-dimensional chemical transport model covering the troposphere and stratosphere. The model can be run in different horizontal and vertical resolution and can be forced by either IFS or ERA-40 data. Two comprehensive and well-tested chemistry schemes are included in the model, one for the troposphere (up to the level of 150 ppbv ozone) and one for the stratosphere. An extensive heterogeneous chemistry has been included. Photo dissociation coefficients are calculated on-line. Emissions of source gases are also included. The Oslo CTM2 model is used in various experiments to look at the chemical changes in ozone. Past time slice runs have used emissions from the Edgar Hyde database to look at the chemical changes up to present. IPCC SRES scenarios have been used for calculating chemical changes in future ozone. Because of large uncertainties in future emissions in the source gases, several time slice runs with different scenarios have been performed. A specific run to look at changes in stratospheric ozone from 1990 through 2000 have been performed, and compared with observations.

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**Department of Physics:** Daily integrated erythemal UV doses are calculated based on a radiative transfer model and measurements with available TOMS satellite instruments. Cloud optical depths used in the model are derived from reflectivity data from the same TOMS instruments. The calculated UV doses are used in UV effect studies (skin cancer and Vitamin D production in humans).

**The Norwegian University of Science and Technology (NTNU)**

NTNU has performed underwater measurements of UV in 2003 and 2005 in the Kara Sea, as well as Trondheimfjorden as a part of the project MAREAS, see section 5.

**Norwegian Institute for Air Research (NILU)**

At NILU, a main focus is to understand the dynamical contribution to the variability in column ozone with a focus on the northern hemisphere mid and high latitudes. Leading modes of climate variability have been shown to induce a strong signature on the trend and year-to-year variability in ozone. These modes include planetary-scale components of the atmospheric circulation (the North Atlantic Oscillation, the Aleutian-Icelandic Seesaw) (Orsolini, 2004) but also more regional patterns, e.g. those associated with blocking phenomena (Orsolini and Doblas-Reyes, 2003).

Another topic is the study of dynamically induced low-ozone episodes (LOE). We explained occurrences of summertime LOEs over the northern high latitudes, and Scandinavia in particular, and looked at their impact on the UV erythemal dose at the ground (Orsolini et al., 2003). An intense LOE occurred over Scandinavia during the European Heat Wave of the summer 2003 (Orsolini and Nikulin, 2005).

We have studied the changes in atmospheric composition (HNO$_3$, NO$_x$), and ozone depletion occurring in the aftermath of the exceptional autumn 2003 solar storms (Orsolini et al., 2005). A highly anomalous layer enriched in nitric acid was observed in the upper stratosphere following the storms, and then slowly descended throughout the winter. Simultaneous observations of NO$_2$, including the nighttime polar stratosphere, revealed strongly enriched NO$_x$ layers following the storms. The formation mechanism for the nitric acid layer does not seem to involve polar stratospheric clouds or aerosols, but rather, is likely to involve heterogeneous chemistry on water ion clusters, a relatively new and unknown topic. In Randall et al. (2005), a multi-satellite intercomparison (POAM, SAGE, MIPAS, OSIRIS) revealed a highly anomalous atmospheric composition in the spring 2004, with unprecedented ozone depletion and NO$_x$ enrichment. It remains to be determined how the unusual meteorological conditions, and possibly, the solar storms in autumn, combined to give rise to this anomalous chemical composition.

Further, the ozone data from Tromsø have been used to establish a multi-decadal UV climatology at a nearby site (Skrova, Lofoten) with meteorological information (Engelsen et al., 2004). For the same area, UV maps have been derived for the period 1984-2002, based on various satellite observation data (Meerkötter et al., 2003). In the frame of the EU project UVAC, it was found that there is a positive correlation between maximum daily doses around 1 May and

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cod recruitment, in contradiction to the work hypothesis assuming a negative influence of UV on cod eggs and larvae.

NILU, in collaboration with the Institute for Community Medicine at the University of Tromsø, pursue research on the relationship between UV exposure, diet and vitamin D status in humans. The project applies UV simulations based on meteorological modelling data, UV measurements, questionnaire forms from cohort investigations, and blood sample analyses.

**DISSEMINATION OF RESULTS**

**Data reporting: Ozone**

Total ozone measurements from the Dobson spectrophotometer in Oslo have been re-evaluated and published (Svendby and Dahlback 2002). The complete set of revised Dobson total ozone values from Oslo is available at The World Ozone Data Centre (WOUDC) [http://www.msc-smc.ec.gc.ca/woudc/](http://www.msc-smc.ec.gc.ca/woudc/). There are established daily routines submitting ozone data from the University of Oslo to WOUDC. The re-analysed total ozone data for Tromsø will be submitted to the WOUDC database in the near future.

At the joint ECMWF/WMO expert meeting on realtime exchange of ground based ozone measurements, held at ECMWF in 1996, the requirements for ozone data for Numerical Weather Prediction (NWP) in realtime were outlined. ECMWF had developed the operational data assimilation system to include ozone retrieval from SBUV and GOME, and requires independent high quality profile data from ground-based systems. For daily validation, monitoring and troubleshooting, it was found that ozone measurements should be available at the centre within 12–24 hours after the sounding.

NILU has collected ozone measurements from Arctic balloon flights through the Nadir database since 1988. Files are transferred and stored in the NASA-AMES 2160 format, and an automatic script has been set up to convert incoming data into the CREX format that is used at ECMWF. This script also performs a series of data quality checks, and can do simple corrections on erroneous input files.

**Data reporting: UV**

NILU has submitted spectral UV measurements from Norway to the European UV database (EUVDB). In the framework of the EU project EDUC, described in section 5, NILU has developed quality assurance software for spectral UV measurements. The QA software is applied automatically to all UV data submitted to EUVDB.

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Information to the public

Ozone
Daily total ozone values for Oslo are available at http://www.fys.uio.no/plasma/ozone/. The latest measured raw data profiles and the latest analysed ozone data from the ALOMAR Observatory at Andøya are available at http://alomar.rocketrange.no/alomar-lidar.html.

UV
NILU has developed a web portal for dissemination of air quality data including UV forecasts for Norway, www.luftkvalitet.info/uv. The content of the UV web pages are:

- UV forecast for three days for Norway and some common destinations for Norwegian tourists
- The UV forecast is given for clear-sky, partly cloudy and cloudy conditions
- Measured UV doses and total ozone values measured at the Norwegian stations
- Facts on UV radiation and the ozone layer

In addition the public may receive UV forecasts for user-selected locations by means of SMS or e-mail. The web application has been developed by NILU in co-operation with the Norwegian Radiation Protection Authority, Storm Weather Center, the Norwegian Pollution Control Authority and the Norwegian Meteorological Institute. During 2005/2006 the UV forecast model would be improved as well as the web-application.

Finally, UV indices and cloud effects measured by a GUV-instrument at the Department of Physics, University of Oslo, are presented and updated every 30 min at: http://www.fys.uio.no/plasma/ozone/.

Relevant scientific papers
The ozone and UV measurements performed in Norway give rise to research in collaboration with national and international partners. The reference list below gives an impression of the international collaboration and ongoing research in the Norwegian ozone and UV scientific community since 2002.


PROJECTS AND COLLABORATION

Norwegian institutions and scientists are participating in numerous international and national projects. The following gives an overview of the most important projects related to ozone and UV research in Norway.
International projects

CANDIDOZ Chemical and Dynamical Influences on Decadal Ozone Change (2002-2005) This EU project aims to identify the earliest signs of ozone recovery. Long-term mid-latitude and polar ozone data sets and global meteorological data are used to assess the roles of chemistry and transport on ozone changes in the Northern Hemisphere stratosphere. Multi-decadal total ozone measurement series are used to empirically investigate the role of dynamical processes on ozone variability. Chemical transport models are used to assess the relative roles of chemistry and transport on ozone changes. CANDIDOZ also considers the possible consequences of climate-ozone interaction. Web-site: http://fmiarc.fmi.fi/candidoz/

EDUCE European Database for UV Climatology and Evaluation (2000-2003) is a scientific EU research project designed to investigate the ultraviolet (UV) radiation climate in Europe. Web-site: http://www.muk.uni-hannover.de/~martin/

HIBISCUS Impact of tropical convection on the upper troposphere and lower stratosphere (UTLS) at global scale (2002-2005). The main objective of this EU-project is to study dynamical, microphysical, radiative and chemical aspects of the UT/LS related to deep convection in the tropics. Web-site: http://www.aero.jussieu.fr/projet/HIBISCUS/en/many/index.html

INSPECTRO Influence of clouds on the spectral actinic flux in the lower troposphere (2002-2005). The overall objective of this EU project is the characterisation of the UV radiation field in the cloudy atmosphere. The objective will be achieved through a combination of theoretical and experimental approaches. Web-site: http://imk-ifu.fzk.de/inspectro/

NDSC: The Network for the Detection of Stratospheric Change is a set of high-quality remote-sounding research stations for observing and understanding the physical and chemical state of the stratosphere. Ozone and key ozone-related chemical compounds and parameters are targeted for measurement. The NDSC is a major component of the international middle atmosphere research effort and has been endorsed by national and international scientific agencies, including the International Ozone Commission, the United Nations Environment Programme, and the World Meteorological Organization. Web-site: http://www.ndsc.ncep.noaa.gov/

OUILT: Quantification and Interpretation of Long-Term UV-VIS Observations of the Stratosphere (2001-2004). The general aim of the EU project was to use the existing ground-based, satellite and balloon-borne UV-visible data as well as 3D atmospheric modelling tools for quantifying ozone loss in the past, to monitor its development in the present and to investigate its relation to active halogen and nitrogen species. Web-site http://nadir.nilu.no/quilt/index.php

SCENIC: Scenario and aircraft emission and impact studies on chemistry and climate (2002-2005) The aim of the EU project SCENIC was to study the atmospheric impact of possible future fleets of supersonic aircraft using state-of-the-art atmospheric models and realistic supersonic fleet scenarios. Web-site: http://www-scenic.ch.cam.ac.uk/

SCOUT-O3: Stratospheric-Climate Links with Emphasis on the Upper Troposphere and Lower Stratosphere (2004-2008). This is an integrated project funded by EU. The central aim of the project is to provide scientific knowledge for global assessments on ozone depletion and climate change for the Montreal and Kyoto Protocols. The SCOUT-O3 project aims to provide new knowledge for EU and national governments, which could be used to develop the European position for sustainable development. SCOUT-O3 involves the research efforts of 59 partners with more than 100 scientific groups; and takes full advantage of new and existing research facilities developed at a national level. Web-site: http://www.ozone-sec.ch.cam.ac.uk/scout_o3/

SOLICE: Solar Impacts on Climate and the Environment (2000-2003) One of the main objectives of the EU project SOLICE was to assess the impact of the solar variability on stratospheric ozone, radiative forcing on climate and surface UV.
UVAC: The Influence of UVR and Climate Conditions on Fish Stocks: A Case Study of the Northeast Arctic Cod (1999-2003) In the frame of this EU project UV climatology were established based on ground-based and satellite measurements of total ozone and cloud coverage. These were combined with marine-biological data sets and field surveys in order to find a possible impact of UV radiation and other climate parameters on the recruitment of Northeast Arctic cod and major elements of its food chain like *Calanus finmarchicus*. Web-site: http://www.nfh.uib.no/prosjektvis.aspx?id=90

VINTERSOL: Validation of INTERnational Satellites and study of Ozone Loss (2002-2004) was a major European field campaign studying stratospheric ozone loss. VINTERSOL was the fourth major European project of its kind, succeeding EASOE (European Arctic Stratospheric Ozone Experiment), SESAME (Second European Stratospheric Arctic and Mid-latitude Experiment) and THESEO (Third European Stratospheric Experiment on Ozone). VINTERSOL-related projects are EUPLEX, HIBISCUS, MAPSCORE, QUOBI, UFTIR, CANDIDOZ, GOA and TOPOZ III. Web-site: http://www.ozone-sec.ch.cam.ac.uk/VINTERSOL/

National projects

AerOzClim: Aerosols, Ozone and Climate (2003-2006). This project is financed through Norwegian Research Council. The main objective of AerOzClim is to improve our understanding of aerosol-climate and ozone-climate interactions, by developing and applying global models in combination with analysis of data, to study processes involved, and to provide improved parameterisations for climate models. Web-site: http://www.geo.uio.no/forskning/atmosfjære/prosjekter/AEROZCLIM/

COZUV: Coordinated Ozone and UV project (1999-2002). The main objective for the COZUV project was to investigate the stratospheric ozone layer in the Northern Hemisphere with various instrumental techniques and to develop and use a three-dimensional chemical transport model. Web-site: http://www.nilu.no/projects/cozuv/

FARIN: Factors Controlling UV radiation in Norway (2002-2006). The Norwegian Research Council funds the project. The main objective of the project is to quantify the various factors controlling UV radiation in Norway, including clouds, ozone, surface albedo, aerosols, latitude, and geometry of exposed surface including a comprehensive instrument comparison with spectral and broad band meters included in the project. The project applies both UV measurements (incl. the Norwegian GUV network) and radiative transfer modelling. Web-site: http://www.nilu.no/farin/

LLAE Light and Life in African Environments (2002-2006). In this project a network of NILU-UV instruments has been established in the African tropical belt: Serrekunda (Gambia), Kampala (Uganda), and Dar-es-Salaam (Tanzania). Further, 3 instruments are located in Kilimanjaro (Tanzania) at 1800 m, 3700 m and 5700 m. Total ozone columns, UV-doses and cloud effects are derived from the measurements at all sites. The project is funded by Norwegian Council for Higher Education’s Programme for Development Research and Education.

MAREAS Material fluxes from the Russian Rivers Ob and Yenisey: Interactions with climate and effects on Arctic Seas (2003-2006) The main objectives of the project are to improve flux assessments of DOC, nutrients and contaminants from the Ob and Yenisey rivers in Russia and to study the hydro-optical properties of the Kara Sea. The linkage between DOC, UV light regimes, primary production and contaminant will also be elucidated.

UTLS-Air: Chemistry in the upper troposphere and lower stratosphere - impact of aircraft emissions (2003-2006). The overall scientific aim of this project is to improve our understanding of the processes controlling the chemistry in the upper troposphere-lower stratospheric region with a
special focus on aircraft impact. The present and future impact of aircraft will be studied. Web-site: http://folk.uio.no/asovde/utls-air/home.html

FUTURE PLANS

A short description of the forthcoming plans are summarised below.

- Department of Geosciences, University of Oslo plans to study the solar – stratospheric relations as a part of more general studies of stratospheric ozone in IPY (International Polar Year) activities.
- NILU has deployed a NILU-UV instrument at the Norwegian Antarctic Troll Station (71° S). Analysis, development, and applications to effect studies are forthcoming.
- Further efforts will be put into the re-evaluation of the Svalbard total ozone data 1950-1962; especially measurements in the ZC mode are not finished yet. More recent data from this site are stored in the WOUDC database (since 1984), but a comparison with TOMS and SAOZ measurements shows significant offsets. Therefore, these data should be quality-assessed.
- The historical Tromsø data before 1950 contain many days where a profile analysis using the Umkehr method may be applicable. The period is very interesting as there were several winters with frequent PSC displays and low ozone values in late winter. However, for such a study funding has to be secured first; it is not achievable in the frame of ongoing monitoring.
- There have also been made efforts to move the Tromsø Dobson instrument, which has not been operated since autumn 1999, to a new site (Bahir Dar, Ethiopia, 10°N), but so far all applications to fund this transfer have been rejected.

NEEDS AND RECOMMENDATIONS

At present, ozone monitoring has a very weak financial basis in Norway. In order to secure a continuous operation of both total ozone monitors and profiling instruments, predictable multi-annual funding schedules should be established in order to free operations from additional funding pathways, e.g. satellite validation projects and short-time research projects. There is a certain need of stable long-term economic support to be able to run instruments properly and continuously since this often is not a part of a research project. The re-evaluation of the historical ozone series has very clearly revealed the importance of observational continuity to establish high-quality long-term data sets, which are essential for climatologically studies in a wider sense.

We also recommend an even closer international collaboration on UV radiation, particularly with respect to quality assurance of measurements, databases and forecasting. Our suggestion is that this collaboration should be supported financially, e.g. through UN.
OBSERVATIONAL ACTIVITIES

Column measurements of ozone and other gases/variables relevant to ozone loss.

The Laboratory of Atmospheric Physics of the University of Panama has been monitoring total ozone column since 1998. Total ozone column is measured with portable multifilter sunphotometers, model Microtops II, manufactured by Solar Light Co. This kind of ozone meter has five channels and measures beam UV-B radiation at the spectral lines of 305 nm, 312 nm, 320 nm and beam infrared radiation at the spectral lines of 940 nm and 1020 nm. Total ozone column is proportional to the ratio between irradiances corresponding to two UV-B wavelengths. A Radiometric and Meteorological Monitoring Network has been established in the cities of Panama, David and Santiago. At the three monitoring sites, the total ozone column shows an annual seasonal behaviour with a minimum value during January (230 DU) and a maximum value during August (280 DU).

Table N° 1 shows the total ozone column monthly mean values at the Republic of Panama.

<table>
<thead>
<tr>
<th>Month</th>
<th>Ozone Column (DU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>231</td>
</tr>
<tr>
<td>February</td>
<td>235</td>
</tr>
<tr>
<td>March</td>
<td>241</td>
</tr>
<tr>
<td>April</td>
<td>247</td>
</tr>
<tr>
<td>May</td>
<td>255</td>
</tr>
<tr>
<td>June</td>
<td>263</td>
</tr>
<tr>
<td>July</td>
<td>273</td>
</tr>
<tr>
<td>August</td>
<td>275</td>
</tr>
<tr>
<td>September</td>
<td>266</td>
</tr>
<tr>
<td>October</td>
<td>254</td>
</tr>
<tr>
<td>November</td>
<td>244</td>
</tr>
<tr>
<td>December</td>
<td>236</td>
</tr>
</tbody>
</table>

Figure N° 1 shows the seasonal behaviour of the ozone column in Panama City, from February 1998 to December 2001.

Figure 1: Total Ozone Column Seasonal Behaviour.
The fitting equation corresponding to the continuous curve is as follows:

$$OZONE = 252 + 30\sin\left(\frac{2\pi [d_n + 225]}{353}\right)$$

Profile measurements of ozone and other gases/variables relevant to ozone loss

Actually, the Laboratory of Atmospheric Physics is not working on the profile measurements of ozone or other gases relevant to ozone loss.

UV measurements

At the three sites of the National Radiometric and Meteorological Network, Ultraviolet B radiation is measured in a continuous way, by means of broad band UV-B meters, model 501 UV-Biometers, manufactured by Solar Light Co. At sites 1 (Panama City) and 2 (David City), global solar radiation and other atmospheric parameters are being measured. Global solar radiation is measured by means of Pyranometers Eppley, model PSP and Pyranometers Kipp and Zonen. For the monitoring of the rest of atmospheric parameters, Campbell meteorological stations has been installed at sites 1 and 2. At site N° 3 (Santiago City), only UV-B radiation is measured up to now. We are planning to install another Campbell meteorological station at site N°3 on October 2005. The three monitoring sites with their respective coordinates are as follows:

<table>
<thead>
<tr>
<th>Table N° 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>National Radiometric Network</strong></td>
</tr>
<tr>
<td>Site</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
</tbody>
</table>

At site N° 1, the monitoring process was initiated on July 1997. At site N° 2, the monitoring process was initiated on December 2001. At site N° 3, the monitoring process was initiated on March 2002. Radiometers and other sensors store data every five minutes, in a continuous way. Data from the three monitoring sites are downloaded from the Laboratory of Atmospheric Physics (Main Campus) through INTERNET by means of a software called PC ANYWHERE. Raw data is then processed, using statistical and graphical software.

Actually, the Radiometric Network administered by the Laboratory of Atmospheric Physics covers one site at the central part (Santiago City) of the Republic of Panama and two sites at the Pacific coastline (Panama City and David City). Up to now, the Laboratory of Atmospheric Physics has no monitoring site at the Caribbean coastline.

Calibration activities

All radiometers and other sensors are calibrated each year. Calibrations have been performed by Solar Light Co and by the Solar Radiation Observatory, at the UNAM, Mexico.

RESULTS FROM OBSERVATION AND ANALYSIS

Table N° 3 shows the evolution of annual total dose in Med registered at the three monitoring sites (Panama City, David City and Santiago City). The station at Panama City has more stored data than the other two, because it is the first Network Site established.
The analysis of the time series for Site N° 1 (Panama City) shows that the highest annual total dose corresponds to year 2000 (7363 MED) whereas the lowest annual total dose corresponds to year 1999 (5697 MED). A high anti-correlation between UV-B dose and cloud cover has been observed. During year 2000, a decrease in cloud cover for Central America was observed. Even during that year, there was a drought all over Central America. A probable cause of this phenomenon is the fact that "The Bermudas" anticyclone was strengthened during several months of 2000. As a consequence of the significant decrease in cloud cover during year 2000, the annual total dose increased with respect to the mean value of annual total dose, which corresponds to the period from 1998 to 2004. During year 1999, a significant increase in cloud cover was observed. Cloudiness was higher during 1999, compared with the other years of the time series. As a consequence of this fact, the annual total dose registered during 1999 was the lowest of the time series.

In Figure 2, the mean monthly dose (mean values has been evaluated for the period from 1997 to 2005) behaviour for Site N° 1 is observed.

In Figure N° 3, the mean monthly dose (mean values has been evaluated for the period from 2002 to 2005) behaviour for Site N° 2 is observed.
At both monitoring sites (Panama City and David City), UV-B mean monthly dose shows a similar behaviour, with a maximum during the dry season (highest levels are registered on March) and a secondary maximum on September-October, during the rainy season. Concerning Site N° 3 (Santiago City), there is not, yet, enough data in order to establish the mean monthly dose behaviour.

Figure 4 shows a contour map of the Monthly Mean Maximum Irradiance vs Local Hour at Site N° 1, for the entire year since 1998 to 2004.
In Figure 5 and Figure 6, the inter comparative UV-B doses for the three monitoring sites, during 2003 and 2004, respectively, are shown.

![Figure 5: Stations inter comparative doses (2003).](image1)

![Figure 6: Stations inter comparative doses (2004).](image2)

Although Panama and David Stations belong to the same climatic zone (Awi zone, according to Köeppen classification), UV-B doses and Indexes are higher at David City due to the proximity of the mountain chain of the central part of the country. This mountain chain acts as a barrier for low cloudiness which is frequently transported by winds proceeding from the Caribbean Sea. Due to this fact, cloud cover over David City tends to be lesser than over Panama City during the morning. Cloud cover at David City increases after local noon due to convection processes which intensify when the Inter Tropical Convergence Zone is passing over the Republic of Panama.

The average total ozone column is **252 DU**. The minimum value (**231 DU**) is registered during the month of January. The maximum value (nearly **280 DU**) is registered during the month of August. Nevertheless, these values lie within the variability margin correspondent to the Panama City latitude. The analysis of the evolution of the total ozone column measured by the Laboratory of Atmospheric Physics of the University of Panama indicates that there is no statistically significant depletion of total ozone column at the latitudes corresponding to the Republic of Panama.
THEORY, MODELLING, AND OTHER RESEARCH

In order to forecast UV Indexes at different regions of the Republic of Panama, the Laboratory of Atmospheric Physics of the University of Panama, is working with the Tropospheric Ultraviolet-Visible Radiation Model (TUV Model) developed by Dr. Sasha Madronich at NCAR. This model, which runs in Fortran 77, has a main programme, approximately 50 subroutines, external functions and nearly 300 data files. With TUV Programme, which is based on “two streams” model, UV irradiance and UV irradiation could be forecasted under cloudless condition as well as under overcast condition.

Cloudiness is the factor which contributes in a more significant way to the spatial and temporal variability of UV irradiance. Theoretically, it is possible to use Transfer Radiative Models in order to assess the transmittance through clouds. The information required to accomplish this assessment is cloud optical depth. However, partial cloudiness is too difficult to model due to the enormous variability of cloud morphologies and multiple heights of clouds bases. Due to this fact, to assess the attenuation on UV-B irradiance caused by partial cloudiness, the Laboratory of Atmospheric Physics of the University of Panama has developed an empirical or parametric model which simplifies this assessment under partial cloudiness condition. This empirical model was presented by the Laboratory of Atmospheric Physics during the Fifth Ozone Research Managers Meeting, celebrated at Geneva on March 2002.

DISSEMINATION OF RESULTS

Data reporting

Actually, the Laboratory of Atmospheric Physics of the Republic of Panama is submitting UV-B data to the RAYENARI Server which is managed by the Solar Radiation Observatory of the Mexican Autonomous National University.

Information to the public

UV Indexes are forecasted daily by the researchers of the Laboratory of Atmospheric Physics. This information is deployed at the Laboratory Web Site (www.igc.up.ac.pa/labfisat/lab220.htm) as well as by some local TV channels. Several educational campaigns have been accomplished in collaboration with the Ozone Unit of the Health Ministry of the Republic of Panama.

Relevant scientific papers

- Determinación de los coeficientes de regresión del modelo de Angström-Page para la Provincia de Panamá; Revista Tecnociencias, Vol.1, N° 1, mayo de 1997.
- Resumen preliminar del monitoreo de la radiación UV-B en la Ciudad de Panamá; Revista Científica Tecnociencias, Vol.1, N° 2, septiembre de 1997.
- Descripción preliminar de la radiación UV-B y del nivel de la columna de ozono estratosférico en la Ciudad de Panamá; Revista Geofísica, IPGH, N° 54, 2001.
- Datos meteorológicos en la cuenca hidrográfica del Canal de Panamá durante el siglo XIX y su aplicabilidad a la variabilidad climática y al cambio climático; Revista Tecnociencias, Vol. 3, N° 2, 2001.
- Estudio climatológico de los niveles de radiación UV-B, columna de ozono total y cobertura nubosa en Panamá; Revista Scientia, Vol. 17, N° 1, 2002.

PROJECTS AND COLLABORATION

The Laboratory of Atmospheric Physics of the University of Panama has received a proposal from GKSS Coastal Research Institute, to collaborate in the Research Project that this Institute develops at “Las Minas Bay”, located at the Caribbean coastline of the Republic of Panama. A formal project with objectives, goals and instrumentation required has been presented to GKSS Coastal Research Institute.
FUTURE PLANS

The Laboratory of Atmospheric Physics of the Republic of Panama is projecting to incorporate, into the actual Research Project, the monitoring process of UV-B radiation, global radiation and other meteorological parameters at the Caribbean coastline of the Republic of Panama. In order to characterize the radiometric and meteorological behavior at the Caribbean coastline, two stations must be deployed over this seaboard. It is recommended that the station N° 4 of the Radiometric Network be installed at Las Minas Bay and that station N° 5 be installed in the University of Panama Regional Centre located at "Bocas del Toro".

NEEDS AND RECOMMENDATIONS

It is important to strengthen the Regional Radiometric Networks and increase the capacity-building for ozone and UV-B measuring stations in developing countries. In order to accomplish this goal, we recommend to look for funding support for those Research Institutions of developing countries that are working on the monitoring of UV-B radiation and ozone, as well as in data analysis and modelling process.

It is urgent to design some procedure which decreases the costs of calibration processes of broadband meters, narrowband filter instruments, ozone meters and other sensors for those Research Institutions of developing countries which are working on this issue. Collaboration of Research Institutions of developed countries, is necessary, in order to facilitate the calibration process for those Research Institutions of developing countries.

****
In the Figure of above appears the daily behaviour of total UV-B measured in day of clear sky in the station that has the Faculty of Exact and Natural Sciences in the University Campus of San Lorenzo.

The maximum value is of the order of 1800 mW/m², and is had around the 12:00 hs local.

The instrument is a Piranómetro UV, YES Model UV-B 1, which also measures the biological effectiveness of solar radiation UVB. First calibration was made in the Meteorological Service of Canada (1996). One second calibration in situ was made by investigators of the Meteorological Service of Spain in 1997.

The Solar Radiation (average every 15 minutes) measured with a LiCor, for the month of January of the year 1999 was between 1,185 and 43 W/m2, that the values of the radiation are high.

Surface Ozone

The Surface Ozone is measurement with a TECO, Model 49/49-PS, for the same period the maximum value is almost 40 ppbv. In the same one it is observed that also superficial ozone is had at night. This can be due to enriched movement shift of air with ozone that lowers from superior levels of the atmosphere due to the thermal contraction of the air.

In the table are the values average of superficial ozone, and the dates in which were surpassed the norms.
<table>
<thead>
<tr>
<th>Days</th>
<th>Average value in 8 hs (ppbv)</th>
<th>Average value in 10 hs (ppbv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>31-ago</td>
<td>89</td>
<td>85</td>
</tr>
<tr>
<td>01-sep</td>
<td>78</td>
<td>73</td>
</tr>
<tr>
<td>02-sep</td>
<td>86</td>
<td>81</td>
</tr>
<tr>
<td>03-sep</td>
<td>74</td>
<td>69</td>
</tr>
</tbody>
</table>

Episode of the year 1999. Measured in station FaCEN - LIAPA.

**Stratospheric Ozone**

Stratospheric ozone on Paraguay is controlled from the data of the TOMS, down are the means values on Filadelfia, Pedro Juan Caballero, Pozo Colorado, San Pedro, Asunción, Pilar, Encarnacion, important localities by its geographic position and greater human population.

Filadelfia is to the west of Loma Plata, 25 km. San Pedro this to 100 km to the northwest of San Estanislao.
Promedios Mensuales de Ozono Estratosférico sobre Filadelfia.
Datos del TOMS. Periodo 1996 - 2005
Promedios Mensuales de Ozono Estratosférico sobre Pedro Juan Caballero.
Datos del TOMS. Periodo 1996 - 2005

Promedios Mensuales de Ozono Estratosférico sobre Pozo Colorado.
Datos del TOMS. Periodo 1996 - 2005
Promedios Mensuales de Ozono Estratosférico sobre San Pedro.
Datos del TOMS. Periodo 1996 - 2005

Promedios Mensuales de Ozono Estratosférico sobre Asunción.
Datos del TOMS. Periodo 1996 - 2005
Promedios Mensuales de Ozono Estratosférico sobre Pilar.
Datos del TOMS. Periodo 1996 - 2005
In all the analyzed stations they are almost observed the same behaviour of monthly distribution during the period from study 1996 - 2005.

<table>
<thead>
<tr>
<th></th>
<th>Encarnacion</th>
<th>Pilar</th>
<th>Asuncion</th>
<th>San Pedro</th>
<th>Pozo Colorado</th>
<th>Pedro J. Caballero</th>
<th>Filadelfia</th>
<th>Max</th>
<th>Maximorum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max</td>
<td>299</td>
<td>301</td>
<td>299</td>
<td>294</td>
<td>293</td>
<td>292</td>
<td>290</td>
<td>301</td>
<td></td>
</tr>
<tr>
<td>Min</td>
<td>246</td>
<td>246</td>
<td>246</td>
<td>244</td>
<td>245</td>
<td>244</td>
<td>241</td>
<td>241</td>
<td></td>
</tr>
<tr>
<td>Promedio</td>
<td>270</td>
<td>269</td>
<td>268</td>
<td>267</td>
<td>266</td>
<td>265</td>
<td>264</td>
<td>267</td>
<td></td>
</tr>
</tbody>
</table>

In the period of study, the values of ozone never were below the 240 UD, which is that never was reached the condition of "ozone hole".

In the Chaco region (Pozo Colorado and Filadelfia) is observed that the variability is small, however in Pedro Juan Caballero is observed greater variability of ozone, is necessary to remember that in Pedro Juan Caballero region the florets is much more exuberant that in the Chaco.
Some works

1) IRRADIANCIA ERITEMICA E INDICE DE RIESGO SOLAR EN ASUNCION, PARAGUAY EN EL PERIODO 1997-1999

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3 Facultad de Ciencias, Universidad Nacional de Asunción, San Lorenzo, Paraguay

Resume:

We analyze solar irradiance in the UV range (290 nm-400 nm) registered with a biómetro having a filter that reproduce the erythemal (alarm of the skin) action spectral. Data were obtained in Asunción, Paraguay between 1997 and 1999, in the months with large aerosols content due to biomass burning. We compare the solar erythemal irradiance, transformed in the solar risk UV index, with results of the solution of the atmospheric radiativa transfer equation, employing the Madronich code. The most important geophysical variable, ozone, is obtained through measurements made with the instrument TOMS (Total Ozone Mapping Spectrometer)/NASA on board of Earth Probe satellite. We employed the method of variable identification in order to determine the aerosol optical depth. In this way we calculate the time variation of UV index, in particular during the biomass burning event that is particularly important in the Chaco and Amazonia regions during August-September of each year. We compare this index with the corresponding one forecasted by CONAE (Comisión Nacional de Actividades Espaciales/Argentina) for the region, giving in general a rather good agreement, except for the days of high aerosol optical depth due to the intense biomass burning.
Some cases showing the relationship between UVB and solar global radiation under cloudless, cloudy and forest fires conditions are presented. The analysis is focused on data collected since 1996 in Asunción City (Paraguay – 25.33°S, 57.52°W; altitude 130m) during wet season (with low aerosol loads and cloudy days) and dry seasons (with biomass burning aerosol predominance in clear-sky days). For the wet season – February/April – a clustering method applied to GOES-8 imagery allows identification of different types of clouds. Aerosol content and statistics for each day (figure 4) – August/September – were assessed using TOMS Aerosol Index. The goals of this preliminary study are: a) illustrate characteristics of UVB attenuation in both seasons; b) evaluate empirical patterns relating UVB fluxes, cloudiness and aerosol presence in the region; and c) determine possible relationships between solar and UVB measurements under clear-sky or cloudy conditions.

Method for identification of different types of clouds and clear-sky pixels in GOES-8 imagery

Can smoke attenuate UV radiation like a cloud?

Attenuation observed in a stratified optically thick clouds.

particulate is frequently transported over South America attaining Paraguay. Particularly in

Figure 4 shows UVB attenuation during biomass burning [BB] episodes during August/September, 1996 to 2001, occurred in South America (mainly in Brazil and Bolivia). BB particles is frequently transported over South America affecting Paraguay. Particularly in 1999, a steady smoke cloud provoked almost 90% of UV attenuation. This is about the same attenuation observed in a stratified optically thick clouds.

Can smoke attenuate UV radiation like a cloud?

The discussion involving both UV and solar radiation suggests a functional relationship between them, under clear-sky and overcast local conditions. The influence of pollution on UV fluxes can be equivalent to cloud effects not only by BB episodes, but also by industrial or urban activities. Additional studies related to this influence are being carried out in São Paulo metropolitan area.
PHILIPPINES

OBSERVATIONAL ACTIVITIES

Column measurements of ozone

On-going Monitoring Activities

In the Philippines, regular monitoring of total ozone and UV-B is conducted by the PAGASA using the Brewer Ozone Spectrophotometer and Dobson Spectrophotometer. Ozone monitoring activities are located at the PAGASA Science Garden Complex in Quezon City (14.6500 ºN, 121.0500 ºE).

Daily measurements of total ozone in the Philippines are being carried out at the local ozone-observing network since late 1970’s. Monitoring of atmospheric ozone and related parameters (e.g. UV solar radiation) are performed as a contribution of PAGASA to the Global Atmosphere Watch Programme (GAW) of the World Meteorological Organization (WMO).

An automated Brewer spectrophotometer (# 127) measures both direct sun and zenith sky measurements several times per day. The Brewer instrument is calibrated with respect to the travelling standard #017 of the Atmospheric Environment of Canada (AES). The Brewer instruments are programmed to make total ozone measurements on the sun and/ or the zenith sky. The Brewers also make Umkehr measurements of the ozone vertical profile and spectral scans of the horizontal UV irradiance. Measurements using Brewer Spectrophotometer started in late 90’s.

Profile measurements of ozone and other gases/variables relevant to ozone loss

At present PAGASA do not have ozone sondes and ozone lidar to make measurements of the ozone profile.

UV Measurements

At the moment we do not have broadband measurements or narrowband filter measurements for UV-radiation monitoring. Such kind of regular measurements are very essential to be developed in our country, but again there is a shortage of funds. What we have right now is a Brewer spectrophotometer which measures UV radiation on a daily basis.

Calibration Reports

Dobson #52

An expert from Japan Meteorological Agency QA/SAC, Koji Miyagawa, made the first field survey in the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), Philippines in March 22-31, 2004 to evaluate, repair and calibrate the Dobson Spectrophotometer (D052). Before the arrival of the expert, Dobson 052 has stopped its operation in preparation for the site transfer. During the instrument check-up the cobalt filter was broken but was repaired with glue and is being reused at present. A defective 470k resistor was replaced. The observers were briefed with the observation method and proper instrument maintenance. A computer software for the total ozone data management was provided and personnel involved in ozone observations were trained regarding its usage. The instrument is now operational in the new site.
Brewer #127

Int’l Ozone Services (IOS) completed the calibration and service of Philippines Brewer #127 during period March 16-20, 2005. This project was to be supported by the World Meteorological Organization (WMO). The instrument has been out of service for the past 5 years due to azimuth tracker power supply failure. The standard lamp (SL) ratios had increased from values of 2160/4420 to 2340/4835 and sensitivity had dropped by ~40%. This large change normally means the PMT filter is deteriorating and probably will need to be replaced soon to stabilize the instrument. The ETC constants were adjusted to values 3580 / 4415 to get best agreement to #017. In the table and graph below are the direct sun daily means and results of #127 and #017 using final constants. Two Sun Scan (SC) test results showed that cal step of 295 was still proper.

UV Calibration:

The UV calibration was checked and the final response file (uvr07705.127) is recommended for future use. The initial UV calibration (uvr07605x.127) showed that the sensitivity had decreased ~40% and due to low counting rates.

RESULTS FROM OBSERVATIONS AND ANALYSIS

Research activities mainly focus on statistical analysis. Trend analysis using ozone data from 1979-2002 (Figure 1) shows that there is no statistically significant trend in the yearly data. As shown in Figure 2, there is a seasonal variation in ozone concentration. Ozone values are high during summer (April-September) and tend to decrease during fall- winter (November-February). There are some data gaps and this can be attributed to instrument malfunction from November ‘89 to Jun’90 and June’95 to April ’96. Other data gaps are caused when the instrument was sent to Melbourne, Australia for general repair and participated in the intercomparison held every four years. The last intercomparison was held in Tsukuba, Japan in 1996.

![Monthly Mean Ozone Concentration](image)

**Figure 1:** Monthly Mean Ozone Concentration (1979-2002).
THEORY, MODELLING AND OTHER RESEARCH

Ozone research activities mainly focus on statistical analyses (trends). The trends of both total ozone amounts are studied regularly.

DISSEMINATION OF RESULTS

Data Reporting

All data are being sent to the WMO World Ozone and UV Data Center operated by the Canadian AES in Toronto.

PROJECTS AND COLLABORATION

PAGASA is an active member of the Technical Working Group for the Phase-out of Ozone Depleting Substances (ODS) in the Philippines. PAGASA participates actively in the evaluation of policies and in designing strategies that are needed in order to phaseout the use of ozone depleting substances in the country. At present the Philippines has made considerable progress in phasing-out CFC’s especially in mobile airconditioning, fire fighting, refrigeration, foam as well as in the solvents industry. As early as in late 90’s most of these CFC’s were already phaseout in the country.

FUTURE ACTIVITIES

- Investigating the causes of high and low concentrations of ozone by correlation analysis with meteorological factors and other pollutants
- Development of UV-B index programme
- Establish Broadband radiometers for additional UV monitoring stations
- Comparison of observations using Dobson and Brewer Spectrophotometer.

NEEDS AND RECOMMENDATIONS:

Operation of the Brewer spectrophotometer in the Philippines remains a big challenge especially for PAGASA with limited resources. Replacement of parts are very expensive. Without the support of WMO and the help of Mr Ken Lamb of the International Ozone Services we cannot sustain the regular maintenance and calibration of instruments. In order to maintain ozone monitoring activities in the Philippines we need the following:
- Technical and financial assistance for the regular calibration of Brewer and Dobson spectrophotometer. Another calibration of the Brewer Spectrophotometer should be planned in 2006 and that a new filter be installed at that time to stabilize the instrument. There is also an urgent need for Dobson intercomparison with the standard Dobson #116.

- Further training of technical personnel in the maintenance of instruments.

- Services of experts to carry out calibration services are very important to ensure continuity of ozone observations especially for Brewer instruments. Support of WMO in order to sustain the regular maintenance and calibration of instruments is very essential.

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POLAND

The ozone and UV-B monitoring and research activities, carried on in two INSTITUTES, are supported by: CHIEF INSPECTORATE FOR ENVIRONMENTAL PROTECTION; NATIONAL FUND FOR ENVIRONMENTAL PROTECTION AND WATER MANAGEMENT; MINISTRY OF THE ENVIRONMENT.

INSTITUTE OF METEOROLOGY AND WATER MANAGEMENT

Monitoring

- The ozone soundings have been performed at Legionowo (52.40N, 20.97E) upper-air station since 1979. Up to May 1993 the OSE ozone sensor with the METEORIT/MARZ radiosounding system was used. Since June 1993 the ECC ozone sensor with OMEGA (since 1997 LORAN) DigiCora/RS80 radiosounding system has been in use. The ozone soundings are launched regularly on each Wednesday. The data are submitted to the WMO Ozone Data Centre regularly on monthly schedule.
- The Legionowo ozone profiles were used in the validation procedures of ozone profiles derived from satellite projects: GOME, POAM III, ILAS.
- Since 1993, on the base of the NOAA/TOVS satellite data, total ozone maps over Poland and surroundings have operationally been performed at a satellite receiving station in Krakow.
- In July 1993 broadband UV Biometers model SL 501 vers. 3, have been installed at three stations in Poland: Leba (54.75N, 17.53E), Baltic Coast, Legionowo (52.40N, 20.97E), Centre of Poland, and in Tatra Mountains: Kasprowy Wierch 1989m (49.32N, 19.98E), operated until 1996, in 1995 a Biometer was installed at Zakopane 857m (49.30N, 19.97E).
- In 2000 two NILU-UV spectral filter instruments were installed at Legionowo, measuring the UV-B, UV-A, total ozone and optical depth.
- Since 2001 the NILU-UV spectral filter instrument has been regularly (yearly), calibrated at NRPA, Norway.
- Surface ozone measurements with Monitor Labs. ML9810 started in 1995 at 3 stations: Leba (54.75N, 17.53E) Baltic Coast, Jarczew (51.81N, 21.98E) Centre of Poland, Sniezka (50.73N, 15.73E) Sudety Mountains.

Research

- Ozone and UV research activities are carried on in the Centre of Aerology in Legionowo in co-operation with the Satellite Research Department in Krakow.
- The Centre of Aerology participates since 1994 in the European Stratospheric ozone campaigns: SESAME, THESEO and O3-LOSS in the Match programme (evaluation of ozone chemical destruction in Polar Vortex). At Legionowo, during the winter/spring months, ozone soundings are performed more frequently, two or three times weekly, according to expected ozone deficiencies over Poland.
- Since 2005 IMWM has been participating in the ENVISAT/SCIAMACHY atmospheric profiles validation programme. At the days, when the ENVISAT satellite orbit passes over Poland, additional ozone soundings are performed.
- The results are submitted operationally to the Data Base at NILU (Norway).
- The ozone research studies focus continuously on the long term changes (trends) in ozone profile in connection with the temperature profile changes and on the case studies of dramatic stratospheric ozone deficiencies, observed with growing frequency during the last years in winter/spring months. These cases are connected either with the excursions of Polar Vortex into the midlatitudes, either with European ozone "mini-holes". The dynamical background of appearance of these cases over Poland is studied.
During the last years, the ozone and UV research activities were directed mainly on UV forecasting. For that reason, several studies have been performed on: short term day to day changes of total ozone; the relation of total ozone to atmospheric characteristics (tropopause, geopotential heights, etc.); validation of total ozone derived from NOAA/TOVS satellite with dobson total ozone; elaboration of a method of one-day total ozone forecast; radiative transfer modelling and adaptation of libRadtran model to local conditions; sensitivity of UVR on ozone profile, clouds and albedo.

In the years 1996-2000 IMWM participated in the UVRAPPF EC project and in the COST-713 Action - UV forecasting.

On the base of these research experiences a method of UV Index forecast for Poland has been worked out and implemented operationally.

In the years 2002-2004 IMWM participated in the EDUCE EC project and since 2004 has been participating in the COST 726 Action.

Public information

Since 1999 the UV Index forecast for Poland has been available from May to August on www.imgw.pl. One of the key tasks of COST-713 Action - UV forecasting was the development of efficient methods for dissemination of the UV Index forecasts and for warning the public against the possible detrimental health effects. A booklet "UV Index for the Public" was prepared (with Polish participation) and published in 2000 (EC publications). In 2001 a Polish version of the booklet, "Indeks UV a człowiek", was prepared and published by the IMWM, sponsored by the Chief Inspection for Environmental Protection.

POLISH ACADEMY OF SCIENCES - INSTITUTE OF GEOPHYSICS

Monitoring

Measurements are carried out at the Belsk Observatory (51° 50’ N. 20° 47’E). Since 1963 total ozone measurements and Umkehr series have been performed by means of the Dobson spectrophotometer. In 1991 Brewer spectrophotometer was installed. Total ozone and Umkehr profile series have been re-evaluated in 1983 and 1987 respectively.

The Dobson and Brewer spectrophotometers are regularly calibrated. The recent calibration of the Dobson instrument took place in 2005 at Hohenpeissenberg, and Brewer instrument was calibrated against Brewer#17 maintained by International Ozone Corporation in 2005 at Hradec Kralove.

The ozone data are regularly submitted to the WMO Data Centre in Toronto. The mean daily values of total ozone are also submitted operationally to the Laboratory of Atmospheric Physics, Aristotle University of Thessaloniki, Greece, and to the World Ozone and UV Data Centre in Toronto.

Systematic measurements of ground level ultraviolet solar radiation (UV-B) with the Robertson-Berger meter have been carried out since 1975. In 1992 UV Biometer SL501A was installed. Spectral distribution of UV radiation has also been monitored with the co-located Brewer spectrophotometer.

The surface ozone measurements with Monitor Labs, ML8810 meter started in 1991, and since 1992 NOx measurements have been performed with Monitor Labs, (ML8841) meter.

Research

The ozone research activities mainly focus on statistical analyses (trends) on local and global scale, and methodology of ozone measurements. The changes in the ozone layer over middle altitudes are examined in connection with changes in the dynamic factors characterising the atmospheric circulation in the troposphere, the lowermost stratosphere, and the stratospheric overworld. The problem of the gradual recovery of the ozone layer in the atmosphere is also investigated. The study is focused on the role played by the dynamical factors in ozone variability,
because natural dynamical processes in the Earth's atmosphere can perturb the recovery of the ozone layer.

Factors influencing the UV radiation (ozone content, aerosol, cloudiness) are studied, with particular emphasis on the response of UV radiation to forcing factors, at various time scales. The Belsk UV data series is the longest time series of UV measurements in Europe and similarly to ozone series is a subject of intensive study. In the studies of the UV-B variability advanced statistical methods such as wavelet decomposition and multivariate adaptive regression spline are used.

Future plans of ozone and UV activities in Poland

- Participation in the COST 726 Action.
- Participation in validation of OMI instrument on board of Aura satellite.
- Participation in the ENVISAT/SCIAMACHY ozone profile validation programme.
- Implementation of an operational monitoring of UV Index from the IMWM network on the web-page.
- Implementation of the DigiCora III/RS92 system to ozone soundings.
- Participation in preparation of the Scientific Assessment of the Ozone Depletion 2006.

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RUSSIAN FEDERATION

OBSERVATIONAL ACTIVITIES

The routine observations of atmospheric ozone include total ozone measurements, vertical profile and surface ozone observations.

Column measurements of ozone and other gases variables relevant to ozone loss.

Daily measurements of column ozone are made by ozone network of Roshydromet service using filter instruments M-124 and by Roshydromet and RAS reference ozone points using Dobson, Brewer and SAOZ instruments. Network included 32 stations on the territory of the former USSR and is technically and methodically, including metrology, maintained by the Voeikov Main Geophysical Observatory (MGO). Observational data from the stations are transmitted to the Central Aerological Observatory (CAO). The CAO archives, accomplishes quality assurance of the data, analyze and monitoring daily ozone fields. The data are also transmitted to the MGO where experts responsible for the status of the network’s instruments analyze them. In routine manner the ozone data are transmitted to the WMO World Ozone and UV Centre in the Environment Service of Canada. Quarterly report “Ozone amount over Russia and the neighbouring territories” are regularly published in the journal “Meteorology and Hydrology”. Roshydromet publishes the status of the ozone layer in the annual edition of the “Overview of the environment pollution in the Russian Federation”.

Profile measurements of ozone and other gases variables relevant to ozone loss.

Ozone profile measurements are made daily since May 2002 by CAO using space observing system Meteor-3M/SAGE III in the frame of US-Russian cooperation, by CAO using balloon ozone sounding during the winter and spring periods at the Yakutsk and Salekhard (67N, 67E) stations, by Lebedev Physics Institute of Russian academy of Science (LPI RAS) at Moscow and Institute of Applied Optics RAS using microwave (142.2 GHz) radiometers. Institute of Optics of Atmosphere (IOA) RAS conducted the regular observations of ozone, nitrogen dioxide and aerosol profiles using lidar.

To processed Meteor-3M/SAGE III raw data CAO developed the algorithm that provide atmospheric transmission profiles for all 86 SAGE III spectral channels and then vertical profiles of ozone in the region 10-80 km, nitrogen dioxide and aerosol extinction in the region 10-40 km /Yu.A. Borisov et al., 2005/.

UV measurements

The Lomonosov Moscow state University made monitoring of the surface UV radiation using the UVB-1 radiometer since 1999. The Brewer instruments located at the Yakutsk station and Obninsk were calibrated to measure the spectral distribution of the surface UV radiation. NPO “Typhoon” (Obninsk) uses Brewer instrument for regular monitoring of UV radiation.

Calibration activities

The Dobson instrument # 107are calibrated with 4 years period, the last one was in June 2003. Calibration is conducted in the European regional centre of the calibration of Dobson's instruments, located in Hohenpeissenberg, Germany. The three Brewer instrument were calibrated by IOS Canada in 2003 and there is a grant from Ministry of education, science and technology of Russian Federation to realize calibration of four instruments on August 2005.
Ozone measurements in troposphere

The regular measurements of surface ozone continue at The Kislovodsk, Moscow, Dolgoprudny, Lovozero, Tomsk and Mondu stations. The most prolonged measurements are taken at the mountain scientific station Kislovodsk (2070 m above sea level) from March 1989. This station has noticeable position in the system of the global monitoring of surface ozone – it is located in the region with the steady climate (Elansky N.F., 2004, Tarasova A.O. et al. 2003). At the station are fixed some prolonged anomalies of the content of ozone, contrasted on the sign to the anomalies, which were being observed at the Alpine stations. This is forces to assume that long-term changes in ozone are closely related with the variability of large-scale circulation (Elansky at al., 2002).

The institute of physics of the atmosphere, the German Max Planck institute of chemistry and CMDL NOAA continued a series of experiments TROIKA. The railroad carriage-laboratory, that is equipped with the automated complex equipment, provides in the Russian territory measurements of surface ozone, reactive gases, greenhouse gases, ozone depleting and other volatile compounds; concentration and the microphysical and chemical properties of aerosol; temperature profile in layer 0-600 m, meteorological parameters, solar radiation and also remote measurements of nitrogen dioxide and ozone profiles in the stratosphere.

RESULTS FROM OBSERVATION AND ANALYSIS

Column ozone

The detailed analysis of global changes in the ozone layer was conducted, in essence, according to the data of TOMS instrument. During the period of 1979 – 2002 the reduction in the average annual value of total ozone in the region extratropical latitudes with an average speed of about 2% per annum is noted. In the northern hemisphere an increase in frequency and amplitude of the negative anomalies of the total ozone in the period 1987-1997 occurred. During this period in the high latitudes of the northern hemisphere the total ozone deficiency amounted to 40%, the duration of anomalies reached to 2 months, while into 1995 and 1997 anomalies were extended almost to half of the territory of Russia. During the last ten years practically everywhere, with exception of the high latitudes of the southern hemisphere, the slow growth of total ozone occurs to the values, close to typical ones for the middle of 1970. The process of an increase of ozone in the northern hemisphere and on the territory of Russia appeared, in particular, in the significant decrease of the basic negative ozone anomaly of the hemisphere – of "spring Yakut" which approximated to Antarctic ozone hole according to such indices as area, duration and the deficiency of ozone, in the separate years.

The mean-zonal sliding trends of total ozone were determined according to the TOMS data in the period from November 1978 through December 2003 (Fig.1).
Figure 1: The time dependence of the mean-zonal (on the 5-degree latitudinal belts) sliding trends of total ozone (in the percentages in 10 years) during the 11-year period according to the TOMS data in the period from November 1978 through December 2003. Years on the horizontal axis correspond to mean value of the 11-year period, vertical axis – latitude /Zvyagintsev A.M. et al, 2002a/.

Ozone profile

The processed Meteor-3M/SAGE III data registered powerful polar stratosphere clouds in the period from the end of December 2004 through February 2005 in the zone of 65-75 degrees of north latitude. Maximum optical cloud thickness was located at heights of approximately 20 km and was observed at temperatures below – 80°C. Under these conditions the extinction of semi-transparent stratosphere clouds exceeded the background values of the aerosol extinction for two orders. The presence of clouds was accompanied by the significant decrease of ozone concentration (Yu. Borisov, Central Aerological Observatory).

Figure 2: Extinction of the aerosol at the height of 20 km for 385nm and 1550nm wavelength. Meteor-3M/SAGE III January-February 2005, 65-75 N.

The analysis of long-term changes in the ozone vertical distribution by balloon sounding stations (Resolute, Cherchil, Edmonton, Goose Bay, Hohenpeissenberg, Payerne, Sapporo, Boulder, Tateno, Kagoshima, Hilo - for all period of measurements no less than 15 years) and
temperature profile for the period from 1970 to 2002 was made. The method of 11-years sliding trend calculation was used. The strongest decrease of the ozone partial pressure in the North hemisphere was detected in the region directly above the tropopause in the lower stratosphere during the period from the end of the late seventies to the early ninetieth last century. The decrease of the ozone partial pressure exactly in this region of heights caused the main contribution to total ozone decrease in the North hemisphere. The correlation between ozone amount and the tropopause height indicates on the relationship between long-term changes of the ozone layer and climate change/Zvyagintsev et al. 2005a/.

The analysis of data of balloon ozone sounding at Yakutsk and Salekhard stations made it possible to obtain the estimation of the chemical destruction of stratospheric ozone in the winter Arctic circumpolar vortex/Tsvekova N.D., 2002, 2004/. So in 2005 was fixed the record value of the chemical destruction of ozone in the stratosphere, which reached 116 Dobson units in total ozone value.

Measurements conducted by IOA RAS during 1999-2002 in the conditions of the long-term background state of the atmosphere were used for the improving the models of the ozone and aerosol vertical distributions.

Ozone in the troposphere

The effect of the long-range transport of ozone and its predecessors to the content of ozone at the Lovozero and Kislovodsk background stations is estimated. The influence was discovered of anthropogenic pollution from Central Europe and Western Europe on both stations and influence of the ejections of the mineral aerosol of North Africa to the content of ozone at the Kislovodsk mountain station.

According to the results of the analysis of surface ozone in the territories of Russia and Europe the conclusion is made that the changeability of ozone in Russia is defined by the same factors as in Europe, but the influence of meteorological conditions in Russia is more strong because of the smaller level of pollution/Zvyagintsev A.M. et al, 2002/.

The analysis is carried out of the worldwide network observations of surface ozone and vertical distribution of ozone in the troposphere during the recent several decades. The conclusion is made that the interpretation of the long-term changes of the ozone in the troposphere must carry out together with changes in the meteorological parameters, first of all in temperature/Zvyagintsev A.M. et al, 2005b/.

THEORY, MODELLING AND OTHER RESEARCH

MGO developed the 3D transport-photochemical model of the stratosphere. The ozonosphere changes caused by Montreal Protocol realization were estimated. The model calculations demonstrate that during period of 1992-2002 the ozone layer evolution depends of the current meteorological situation for the most part and only 1-2% was caused by implementation of the Montreal Protocol/Egorova T.A. et al., 2003/.

The estimations of the ozone decreasing during spring 1993-1996 and 2002 over the Antarctic are conducted. For calculation the assimilated meteorological reanalyzed UKMO data were utilizes. Successful description of the heterogeneous photochemical processes allow to achieve a good agreement with the results of observations made at the Syowa (Japan), Marambio (Argentina) and Amoosden-Scott stations and also render the unique behaviour of the ozone hole in 2002/Ozolin Yu.E. et al., 2003/.

At the Novosibirsk State University the calculation of natural and anthropogenic factors to long-term changes in the ozone layer in the last decades of the 20th century is studied using a numerical two-dimensional ozonosphere model with self-consistent calculation of photochemical, radiative, dynamic, and microphysical processes. Changes in the ozone layer calculated from data
in anthropogenic pollution, 11-year solar UV flux variations, and volcanic eruption agree quite well with the global ozone trends observed in the last 25 years of the 20th century (Demidov I.G. et al., 2005).

Studies are carried out on the development of the methods of processing and analysis of data of IR- sounder IASI of high spectral resolution. This instrument is intended to launch on the future European meteorological satellite. The method of evaluating the vertical distribution of ozone according to information IASI is proposed (Uspensky A.B. et al., 2003)

Within the framework of project TRIDES it is shown that the predecessors of the toxic chlororganic connections, which are formed with the participation of ozone, are not only the anthropogenic pollution, but also the products of the vital activity of the halo-bacteria, that live in salt waters of Caspian and Aral Seas and lakes of Central Asia /L. Weissflog et al., 2005/.

The estimation was carried out of the emission of ozone depleting substances in the territory of Russia according to observations of the TROIKA experiment. It is shown that the emissions of such substances are small, with exception of Freon -12 /D.F. Hurst et al.,2004/.

DISSEMINATION OF RESULTS

Data reporting

The M-124 network observations of the total ozone are daily transmitted to the WOUDC. The results of observations by Dobson instrument #107 (Dolgopruny) and by Brewer (Yakutsk) instrument are monthly transferred in WOUDC. Total ozone data base of Brewer observation at the Kislivodsk station was transferred in WOUDC. Observational data of SAOZ instrument located at the Salekhard are transferred once a week to the French centre of SAOZ data collection. Data of balloon ozone sounding at the Salekhard and Yakutsk stations during the winter-spring period of 2003, 2004 and 2005 are represented into the NILU data base.

Information to the public

A technology for UV forecasting on the Russian territory was developed. The technology utilizes the M-124 network observations, satellite (METEOSAT) cloud cover and surface albedo data to retrieve current and forecast the next day UV-B surface radiation. Technology is used irregularly, only in the case of the strong negative anomalies of total ozone.

Relevant scientific papers


Zvyagintsev A.M., Kruchenitsky G.M., Chernikov A.A. Changes of the vertical ozone distributions in the stratosphere and there correlation with tropopause height changes// Proceedings of the RAS. Atmospheric and Oceanic Physics, 2005a, V41 Suppl.4, P.1-10 (In Russian).


Uspeisky A.B., Romanov C.V., Trotsenko A.N. Simulation of remote measurements of the vertical distribution of ozone in the atmosphere according to the data of the satellite IR sounder of highly spectral resolution. Exploration of the Earth from space, 2003, Vol.1, P.49-57 (In Russian).


PROJECTS AND COLLABORATION

US-Russian Meteor-3M/SAGE III project.
European project QUOBI.
European project SCOUT-03.
TRIDES Project.

Agreement between Roshydromet and Finnish Meteorological Institute (item 2. Stratospheric ozone and UV radiation measurements)

FUTURE PLANS

To continue monitoring the total ozone and vertical distribution of ozone with the use of ground-based, balloon and satellite observation facilities.

To develop together with the Belarus’ country satellite spectrophotometer SFM -2M intended for the measurements of the vertical profile of ozone in the upper troposphere, the stratosphere and the mesosphere.

In order to equip ozone network stations with the instruments of contemporary level, MGO developed and prepared the experimental sample of ozone UV- spectrometer for measuring the column ozone, the spectral composition of the UV radiation, the optical density of aerosol, etc. Spectrometer is developed on basis of diffraction grating and CCD and it separates the spectrum of radiation in the range 230-420 nm with the 0.9 nm resolution.

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SLOVAKIA

Atmospheric ozone and UV-B monitoring is mainly conducted by the Slovak Hydrometeorological Institute (SHMI). Research is mostly carried out by the Geophysical Institute of the Slovak Academy of Sciences (GISAS).

OBSERVATIONAL ACTIVITIES

Column measurements of ozone

Total column ozone measurements have been performed by the Centre of Aerology and Ozone Measurements (CAOM) of SHMI since August 1993. The Global Ozone Observing System (GOOS) station No. 331 is situated at Poprad-Ganovce (49.03N, 20.32E, 706 m altitude). The Brewer ozone spectrophotometer MKIV No.097 is used for routine measurements. Poprad-Ganovce is Global Atmosphere Watch (GAW) regional station for total column ozone monitoring.

Ground level ozone is monitored at about 20 stations. Activities have been outlined in the Report of the Fifth Meeting of the Ozone Research Managers and will not be discussed in this report.

Profile measurements

Umkkehr vertical ozone profiles are measured with the Brewer spectrophotometer by proper weather conditions in the morning.

UV measurements

Broadband measurements

At present the Slovak UV-B network consists of five stations. Four of them are equipped with SOLAR Light 501 UV Biometers. Three stations belong to SHMI (Kosice, 48.70N, 21.27E, 230 m altitude, in operation since 1997, Bratislava 48.17N, 17.12E, 287 m altitude, since 1998, Poprad-Ganovce, since 1999) and one station situated in mountains belongs to GISAS (Skalnate Pleso, 49.20N, 20.23E, 1778 m altitude, since 2001). GISAS also measures the global ultraviolet radiation with Eppley UV-radiometer model TUVR for the wavelength range 290-385 nm located at Stara Lesna (49.15N, 20.29E, 808 m altitude, in operation since 2002).

Narrowband filter instruments

No UV narrowband instruments are installed at SHMI and GISAS stations.

Spectroradiometers

Spectral measurements of the solar UV-B radiation (in the region 290-325 nm at 0.5 nm increments) have been performed with the Brewer spectrophotometer at Poprad-Ganovce since August 1993. Observations are scheduled at regular time intervals. Poprad-Ganovce is GAW regional station for spectral UV-B monitoring.

Calibration activities

The Brewer No.097 is regularly calibrated against World Travelling Standard Brewer No.017 every two years. Since the last Meeting of the Ozone Research Managers the instrument has taken part in two international comparisons and calibrations (Warsaw 2003, Hradec Kralove 2005).
The CAOM maintains the SL 501 UV Biometer designated as the national reference instrument. The instrument was compared with the Czech reference UV Biometer during the Brewer calibration campaign in Hradec Kralove in May 2005. In June all network UV Biometers in Slovakia were calibrated with the reference instrument.

UV-B data series from Bratislava (1997-2004) and Poprad-Ganovce (1999-2004) have been recalculated according to calibration results.

RESULTS FROM OBSERVATIONS AND ANALYSIS

Figure 1 shows monthly means of total column ozone, UV-B dose and sunshine duration at Poprad-Ganovce. Small negative trend in total column ozone and positive trends in UV-B dose and sunshine duration have been observed during the period 1995-2004.

THEORY, MODELLING AND OTHER RESEARCH

The effect of total ozone change on the biologically effective UV radiation has been studied using total ozone and spectral UV radiation measurements of the Brewer instrument and broadband UV-Biometer measurements at Poprad-Ganovce. The clear-sky morning UV-B irradiances (recalculated to mean Sun – Earth distance) were interpolated to fixed solar zenith angle (SZA). The obtained values of radiation amplification factor (RAF) were compared with that ones calculated from total ultraviolet visible radiation model (TUV model, Madronich, 1993). Good agreement between the RAF obtained from measurements and the RAF calculated by TUV model was achieved for large SZA 50° and 60°.

Atmospheric aerosol change effect on the biologically effective UV radiation was studied using aerosol optical depth (AOD) for radiation at wavelength 320.1 nm (AOD_{320}). AOD_{320} was calculated by Langley plot method from direct monochromatic solar irradiance observed by Brewer spectrophotometer during the period 1993-2002.
Sensitivity of the biologically effective radiation to the surface albedo change was determined using comparison between clear-sky UV-B irradiances observed under condition with continuous snow cover and without any snow cover at selected localities – Poprad-Ganovce (valley position), Stará Lesná (foothill of the High Tatras mountain) and Skalnaté Pleso (mountain conditions). UV-B data were recalculated to fixed total ozone content (300 DU) and to mean Sun – Earth distance.

Effect of altitude on the UV-B radiation has been investigated using comparison between UV Biometer data obtained at localities with significantly different altitude and relatively small horizontal distance.

Cloud effect on the UV-B radiation was studied using Brewer spectrophotometer measurements and cloud characteristics saved in Brewer commentary files.

A present research is oriented on determination of relations between solar UV-B radiation and meteorological and radiative proxies to model UV-B radiation in the past (COST-726 project).

DISSEMINATION OF RESULTS

Data reporting

The Brewer data are submitted to the World Ozone and Ultraviolet Data Centre (WOUDC) in Toronto every month. Total ozone and UV-spectral raw data are monthly submitted to Brewer Data Management System (BDMS) in Toronto to process and submit it to WOUDC. Since winter 1993 the station participate in WMO GAW Northern Hemisphere Ozone Mapping Experiment by daily submitting of total ozone data to Ozone Mapping Centres.

Information to the public

The report on present state of ozone layer and intensity of solar damaging UV radiation (Erythema effect) for sunny day is sent to Slovak Press Agency twice a day. It is regularly utilized by television, broadcast and newspapers.

CAOM Poprad-Ganovce also has been preparing short report on the total ozone amount and recommended maximal sunburn time. This report is propagated by mobile telephone service.

SHMI provides regular total column ozone and UV Index (March-September) forecast. It is propagated by SHMI Web site.

Ministry of Environment and SHMI have equipped big cities with electronic billboards. Both total and surface ozone data are included into presented information.

The analyze of total ozone, surface ozone and solar UV radiation is regularly included in the annual publication: "Air Pollution in the Slovak Republic".

Relevant scientific papers

Please see references.

PROJECTS AND COLLABORATION

SHMI participate in international ozone and UV projects mainly by regular submitting of the good quality ozone and UV-B data to the WOUDC.

At national level the task: "UV Biometer calibration methodology and UV-B observation series reconstruction" is solved at SHMI and the project: "Effect of atmospheric boundary layer on radiative fluxes and heat balance of Earth’s surface" has been solved at GISAS.
Both projects are included into COST action 726: "Long term changes and climatology of UV radiation over Europe"

FUTURE PLANS

Improvement of the UV Index forecast involving atmospheric aerosol effect on the UV-B irradiance variability. It needs precise measurements of aerosol optical depth in the UV range of the solar spectrum.

Determination of relations between UV-B radiation and meteorological (cloudiness, aerosol content, snow cover) and radiative (total solar radiation, sunshine duration) proxies to assess UV-B irradiance at different places in Slovakia at present and in the past.

Participation in international calibration of broadband instruments planned for 2006 in frame of COST action 726.

Looking for a relevant partner to study some aspects of the damaging solar UV radiation impact on human health.

NEEDS AND RECOMMENDATIONS

Regular international comparison of broadband UV radiometers is extremely needed to keep the homogeneous scale.

References


INTRODUCTION AND OBSERVATIONAL ACTIVITIES

The South African Weather Service (SAWS), an agency of the Government Department of Environmental Affairs and Tourism, is the national focal point of ozone monitoring and research activities in South Africa. These activities are greatly enhanced by collaboration with a few centers involved but mainly the Universities.

The ozone monitoring and research activities are conducted within the context of the World Meteorological Organizations (WMO) Global Atmosphere Watch (GAW) programme. The Global Atmosphere Watch component of the South African Weather Service (SAWS), as part of its Public Good Service, are conducting certain specialized atmosphere monitoring and research services for the Department of Environmental and Tourism Affairs (DEAT), in order for the Department to fulfill its national, regional and international obligations. The Department has the responsibility for implementing the Montreal Protocol and facilitates the coordination role with industry. South Africa is dealing effectively with its commitments under the Protocol.

The depletion of the stratospheric ozone layer, increases in troposphere ozone, higher levels of acidity in rain, rising carbon dioxide and methane concentrations, and changes in the radiative balance of the earth-atmosphere energy system - all reflects the increasing influence of human activity on the global atmosphere, the life-support system of planet Earth. Environmental issues and policy matters have to play a pivotal role in meeting the developing needs and challenges of the people in a new democratic South African Society. Clauses in protecting and respecting the environment in a sustainable context, is embedded in the South African Constitution.

Worldwide it is proven that sustained systematic observation only survives under the auspice and responsibility of a Government. More and more of these specialized environmental monitoring activities are shifted towards the responsibilities of National Meteorological Services. This is undoubtedly a core service resulting from international agreements undertaken by government of the Republic of South Africa.

Figure 1: Regional Networks.

CAPE POINT, GLOBAL GAW STATION – TRACE GASES
IRENE AND SPRINGBOK – OZONE DOBSON # 89 AND # 132 (IRENE SHADOZ SITE)
DE AAR - BSRN STATION - SOLAR RADIATION
NATIONAL UV-B REAL TIME MONITORING NETWORK
The first South African column ozone measurements were made during 1964 until 1972 with Dobson #089 operating from Pretoria. Reinstating South Africa’s commitment to the Vienna Convention, the Weather Service now operates two Dobson ozone spectrophotometers, #089 at Irene near Pretoria (25.9 S, 28.2 E) since 1989, and #132 at Springbok (29.7 S, 17.9 E) since 1995. Both these instruments have been regularly calibrated with reference to the world standard.

A WMO/GAW International Comparison of Dobson Spectrophotometers (SAWB2000IC) was organized by the World Meteorological Organization and the South African Weather Service in close cooperation with the USA National Oceanic and Atmosphere Administration’s Climate monitoring and Diagnostics Laboratory (NOAA/CMDL). This first Africa, WMO Region-I Intercomparison event was conducted in Pretoria from 18 March – 10 April 2000. In addition the Czech Republic Hydro meteorological institute continued to provide expert assistance to southern African training of Dobson operators.

The South African Dobson observation programme includes daily total ozone measurements (mostly high quality direct sun observations), and weekday Umkehr observations during sunrise. On average 500 total ozone readings per month are collected, and weather permitting between 10 and 15 Umkehr measurements. Final Umkehr results are still hampered by the inadequate knowledge that exists within our institution and collaboration partners are sought for assistance.

Since November 1998, the Weather Service has been fortunate to reinstate its ECC RSG80-15GE Ozonesonde sounding programme, which operated during the period 1990 until 1993. Weekly ozonesonde soundings are conducted. This data is shared with the Southern Hemisphere Additional Ozonesondes (SHADOZ - http://croc.gsfc.nasa.gov/shadoz/) programme from NASA, USA, which also is submitted to WOUDC. Since 2000, the Irene ozonesonde station was officially accepted into the SHADOZ network. The Irene Ozone Launching programme also now forms part of the AURA validation of OMI/TES and data after each launch is submitted in near real time.

Surface ozone measurements are undertaken at Cape Point since 1982. Our programme has also extended surface ozone measurements to the South African National Antarctic Expedition Base (SANAE IV) in Antarctica since December 2003. The SAOZ instrument which operated at SANAE during early 1990’s, has been refurbished at LSCE, CRNS, France and it is expected to be re-instated at SANAE in December 2005.

Other gases and profile measurements

The pristine location of Cape Point (34.3S, 18.5E) enables measurements to be made in air that has passed over the vast clean Southern Ocean. Such long-term observations are representative of background conditions, making it possible to detect changes in the atmospheres composition. The Cape Point GAW Laboratory is also scientifically twinned with a research partner, namely the Fraunhofer Institute for Atmospheric Environmental Research (IFU) in Garmisch, Germany, now IMK-IFU (Forschungszentrum Karlsruhe).

Measurements include a wide range of parameters namely: - surface O₃, gases which lead to stratospheric ozone depletion such as: CFCl₃, CCl₂F₂, CCl₂F-CClF₂, CH₃CCl₃, CCl₄ and N₂O, greenhouse gases in the troposphere such as CO, CO₂, and CH₄. UV-A and UV-B and global radiation (total and diffuse) are also measured as well as the normal surface meteorological parameters. Radon measurements to assist with the classification of air masses arriving at Cape Point, have been successfully established over the last five years. Regular scientific audits from EMPA, Switzerland for surface O₃, CO and CH₄ have been successfully conducted over the past seven years. Last year, the WCC-N₂O (IMK-IFU and Umweltbundesamt) conducted and audit for N₂O at Cape Point.
Ultraviolet-B measurements

Since January 1994 the Weather Service has maintained a routine programme for monitoring erythemally weighted UV-B radiation at Cape Town (34.0S, 18.6E), Durban (30.0S, 31.0E) and Pretoria (25.7S, 28.2E), De Aar (30.7S, 24.0E) and Port Elizabeth (33.9S, 25.5E). The equipment used in this network is the Solar Light Model 501 Robertson-Berger UV-Biometer. The programme was motivated by and in collaboration with the School of Pharmacy at the Medical University of Southern Africa (MEDUNSA), near Pretoria.

Since December 2001, the UV-Biometers are directly linked on the Services wide area network, and available in real-time on the SAWS WWW-site. UV-B forecasts are also issued for the Cape Town, Durban and Pretoria-Johannesburg metropolitan areas since 1 December 1997. The main purpose of the UV-Biometer network is to make the public aware of the hazards of excessive exposure to biologically active UV-B radiation, and it contributes to the schools awareness programmes for education. Regular enquiries from scholars are dealt with to satisfy their need to acquire more ozone and ultraviolet radiation knowledge. Two UV-B narrow-band (~306nm) Kipp & Zonen sensors are located at the two Dobson sites to investigate possible trend correlation between ultraviolet radiation and total ozone. Great strides have been made to develop our own numerical weather predictions outputs for UV indices. Celebrations around 16 September, each year, usually focuses to create public awareness. Once a year on this day it is also dedicated to the hard working ozone observers and technicians gathering the measurements.

![Figure 1: SAWS Numerical Product Developed for UV Index forecasting with cloud cover.](image)

Calibration activities and data submissions

All primary ozone and trace gas data are submitted regularly to WMO recognized World Data centers. Dobson column ozone is submitted to WOUDC, Toronto, Canada. Since the inception of the Dobson Programmes these instruments have been internationally calibrated through inter-calibration campaigns as supported by WMO. The next all-African Dobson calibration is scheduled to take place in South Africa during 2008, currently recognized as an unofficial Regional African Calibration Centre.

Regular scientific audits from EMPA, Switzerland for surface O₃, CO and CH₄ have been successfully conducted over the past seven years. Last year, the WCC-N₂O (IMK-IFU and Umweltbundesamt) conducted and audit for N₂O at Cape Point. Next laboratory calibrations are scheduled for September 2006. The regular scientific audit from EMPA, Switzerland, continues to
reveal very successfully surface ozone calibrations at the Cape Point Laboratory, which also in future will serve as calibration facility for regional instruments.

RESULTS FROM DATA OBSERVATIONS

![Monthly Mean Dobson Ozone Values](image)

*Figure 2: Only Column Total Ozone are displayed.*

COLLABORATION - NATIONAL AND INTERNATIONAL

Ozone and related research are conducted sporadically within the country, mostly at a few academic institutions such as the University of Kwazulu Natal in Durban, the University of Cape Town and the University of the Witwatersrand in Johannesburg. Research interest of the effects of ultraviolet radiation amongst the medical and environmental sectors has also become more pronounced.

South African, Prof Roseanne Diab from the University of Kwazulu Natal and Mr G Coetzee of SAWS are both members of the International Ozone Commission [http://ioc.atmos.uiuc.edu/](http://ioc.atmos.uiuc.edu/) Mr G Coetzee is also a member of the established WMO-Ad Hoc committee on Dobson Operations. Prof. Roseanne Diab has been participating in many international ozone assessments, and has also been actively involved in strengthening ozone research/collaboration efforts throughout Africa. During early 2004 a very successful “African” ozone workshop was also conducted in Durban. Mr E-G Brunke of the Cape Point GAW laboratory is a member of the WMO SAG GHG.

South Africa must also acknowledge its many international collaborators with specific references to international programmes and Institutions such as:

- SHADOZ/NASA/GSFC/USA
- USA NOAA CMDL
- WMO - World Meteorological Organisation
- WOUDC and ARQP, Toronto, Canada
- GAWTEC [http://www.schneefernerhaus.de/e-gawtec.htm](http://www.schneefernerhaus.de/e-gawtec.htm), Germany
- LSCE, CNRS and DEBITS, Paris and Toulouse, France
- EML, New York, USA
- NORWEGIAN – SOUTH AFRICAN BILATERAL COOPERATION
- THE CZECH NHMS
FUTURE PLANS AND RECOMMENDATIONS

In collaboration with various research institutes we still would like to improve the general circulation models for ozone and UV-B predictions. This will increase our understanding and ability to render a more efficient public service. The Weather Service is continuing with efforts to ensure real-time data availability on the SAWS WWW-site at http://www.weathersa.co.za

The installation of spare Dobson spectrophotometers and other instruments on "permanent lease" from more Europe partners will be established to complement the Southern African and surrounding Oceans observing platforms. In December 2005, the SAOZ instrument which has been refurbished at LSCE will once again operate at the South African National Antarctic Base, SANAE IV and form part of the global network of SAOZ instruments.

Further strengthening our collaboration in the Southern African regional context to enhance monitoring and research effort such as with the establishment of the Dobson #15 at Maun, Botswana in 2004. This is where EU Partners and resources can play a significant role to assist in partnerships and collaborated projects.

The International Polar Year (IPY) also provides ample opportunity for the extension of collaboration and monitoring networks in the southern Oceans and Antarctica. Plans are being develop to enhance RSA ozone and trace gas measurement activities, to the South African National Antarctic Base at SANAE. These could also include the enhancement at the monitoring stations at Gough (40S, 10W) and Marion (47S, 37E) islands where permanent South African Weather Stations are operating.

Enhancing ozone and trace gas activities on the African continent, remains a great need and a great challenge. Many countries have expressed their willingness to participate and to become more actively involved in sustaining measurement programme in some form. The challenge, we as scientific community thus faces, is how to assist those who also needs further investment, capacity and encouragement to secure and enhance the global network. Under the auspice of the WMO GCOS programme more opportunities can also include ozone and meteorological related observation.

The small South African ozone community on this front is also committed to collaboration in our region to enhance future ozone monitoring and related parameters research activities. With this we draw inspiration from the New Partnership for Africa’s Development (NEPAD) plan.

RELEVANT RESEARCH PAPERS (co-authored)

Schmalwieser Alois W.; Schauberger Günther; Weis Philipp; Stubi Rene; Janouch Michal; Coetzee Gerrie J. R.; Simic Stana, Preprocessing of total ozone content as an input parameter to UV Index forecast calculations, J. Geophys. Res. Vol. 108 No. D6, 2003


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SPAIN

OBSERVATIONAL ACTIVITIES

Continuous ozone, UV radiation and related atmospheric compounds monitoring and research is mainly conducted by the Instituto Nacional de Meteorología (INM) and the Instituto Nacional de Técnica Aeroespacial (INTA). The Departments of Physics and Meteorology of several Spanish universities do research on ozone and UV. Most of the national actions are financed by the National R+D Plan of the Ministry of Education and Science.

**Column measurements of ozone and other gases/variables relevant to ozone loss**

The longest total ozone record in Spain (since 1980) has been obtained with the Dobson spectrophotometer #120 installed at "El Arenosillo" station (Huelva) and operated by INTA. This instrument has been used in a number of intercomparisons at Davos and is in operation at present. The latest calibration was held at Hohenpeissenberg in July 2003.

**Brewer spectrophotometer national network**

INM operates a national Brewer spectrophotometer network (Figure 1 and Table 1), partially financed by the National R+D Plan of the former Ministry of Science and Technology. The Brewer at the “El Arenosillo” station, financed by the Andalusian Regional Government, is managed by INTA. This network provides total ozone and spectral UV that is real-time monitored through the INM’s intranet.

![Figure 1: National UV broadband radiometer and spectrophotometer network.](image)

Since November 1999 the Brewer network has performed a common measurement schedule (ozone and spectral UV) on a daily basis. This information is stored and validated in the centralized INM database.
The Network for the Detection of Stratospheric Change (NDSC) Programme at the Izaña Observatory

Since 2000/2001 the Izaña Observatory has participated in the NDSC network as a complementary station in the following four programmes:

- Total ozone with a double Brewer spectrophotometer managed by INM.
- ECC ozonesonde programme operated by INM.
- UV-VIS: A photodiode array Spectrograph from INTA has been running at Izaña since December 1998. This instrument is able to measure total columns of O$_3$, NO$_2$ and H$_2$O. Retrievals of iodine monoxide (IO) are being explored to detect whether or not this radical is in measurable magnitudes in the atmosphere outside of the boundary layer. A new UV photodiode array spectrograph from INTA was installed at the Izaña Observatory in November 2001 to expand the capabilities of the previous ones to BrO. Bromine has 50 times more Ozone Depletion Potential (ODP) than Chlorine and its concentration in the atmosphere is still increasing due to Methyl Bromide (CH$_3$Br) and Halon emissions.
- A UV-VIS (DOAS) spectrometer instrument (EVA) from INTA for measuring total column NO$_2$ and O$_3$ has been operating at Izaña Observatory since 1993.
- FTIR: since February 1999 a ground-based FTIR (Fourier Transform InfraRed) spectrometer (Bruker IFS 120 M) is operated at the Izaña Observatory by the Institut für Meteorologie und Klimaforschung (IMK) (Forschungszentrum Karlsruhe, Germany). Besides zenith column amounts (ZCA) of trace gases such as O$_3$, H$_2$O, HDO, N$_2$O, CH$_4$, HF, HCl, ClONO$_2$, NO, NO$_2$, and HNO$_3$, profiles of gases with narrow absorption lines such as O$_3$, NO, HCl and HF can be retrieved. In March 2005 a new FTIR spectrometer has been installed at Izaña Observatory.

Table 1: National Brewer Spectrophotometer network.

<table>
<thead>
<tr>
<th>Station</th>
<th>Location</th>
<th>Instrument</th>
<th>Institution</th>
<th>Since</th>
<th>Last calibration</th>
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</table>

The Antarctic UV-VIS network

In the framework of several projects financed in previous convocations of the National R+D Plan of the Ministry of Science and Technology, three UV-VIS spectrometers (EVA) designed and developed at INTA to measure column NO$_2$ and O$_3$ were installed at the permanent Argentinean bases of Belgrano (77° 52’ S 34°37’ W), Marambio (64° 14’ S 56°37’ W) and Ushuaia (54° 48’ S 68°19’ W), respectively, in 1994. The selected stations are scientifically interesting for the study of polar atmosphere as the southernmost, which is Belgrano, is mostly located inside the vortex, Marambio on the edge, and Ushuaia right outside the vortex. A new UV photodiode array
spectrograph from INTA has been installed in October 2002 in Marambio (Antarctica) to retrieve zenith column amounts of BrO, OClO.

The main objective of this network is to provide both long term and near real-time observations of column $O_3$ and NO$_2$, in order to characterize the polar vortex. A description of the network, including instruments and stations, as well as the results of this network can be found at http://www.inm.es/mar

**INTA's station at Keflavik (Iceland)**

A long-term ozonesounding programme between INTA and IMO (Icelandic Meteorological Office) is running at the subArctic station of Keflavik (Iceland, 64°N, 22°W). Activities devoted to monitoring the ozone layer in the region of influence of the stratospheric polar vortex started in 1991 within the First Coordinated European Experiment for Ozone depletion Studies (EASOE). Since then and to date, ozonesondes have been launched during winter through a number of European projects (SESAME, OSDOC, THESEO, QUOBI, SCOUT-O3) and will continue in the near future.

**Profile measurements of ozone and other gases/variables relevant to ozone loss**

The ECC ozonesonde programme was initiated in November 1992 as part of the GAW programme at Izaña Observatory. The ozonesoundings are launched from Santa Cruz de Tenerife station (36 m.a.s.l.), at a distance of 28 Km from the Izaña Observatory, on a weekly basis and without any interruption since 1992. During intensive campaigns more than twenty sondes per month are launched. This is a NDSC programme. Continuous total ozone monitoring since May 1991, including two Umkehr profiles per day (since January 1992) is performed using Brewer spectrophotometers at Izaña Observatory (see Table 1).

ECC ozonesondes have been launched on a weekly basis at Madrid by INM since 1992, although with some interruption periods. INTA operates an ozonesounding facility at the El Arenosillo station with sporadic launches. Intensive campaigns, most of them financed by European projects, are frequently carried out at the El Arenosillo station.

A long-term ozonesounding programme between INTA and DNA/IAA (Argentina) has been running at the Belgrano station (Argentina, 78°S, 35°W) since 1999. Since then and to date ozonesondes have been launched through a number of Spanish (MAR and “Caracterización del vórtice Antártico y transporte meridional a partir de observaciones remotas de trazadores estratosféricos”) and European projects (QUOBI).

INTA and INM have participated in previous years, and participate nowadays, through the mentioned ozonesounding stations, at Keflavik, Madrid and Tenerife in the Match Experiment coordinated by the AWI (Alfred Wegener Institute, Germany). This experiment was carried out in connection with the European projects (EASOE, SESAME (OSDOC), THESEO (O3-LOSS), EUROSOLVE). Sondes were both European and nationally financed.

**UV measurements**

**Broadband measurements**

A national UVB broadband network of 17 Yes-pyranometers (Figure 1), managed by INM, has been fully operational since July 1999. This network has been partially financed by the National R+D Plan.

The group of photobiology and algae biotechnology of the Ecology Department at Malaga University manages the “UVIFAN” UV network, based on broadband Eldonet (European Light Dosimeter Network) radiometers, in the Andalusia region. This network has been financed by the
INTA is collaborating with the Institute of Aerospace Medicine from DLR on solar UV dosimetry by biological sensors (biofilms @). The collaboration covers the measurement campaigns at different locations in Spanish and German territory and the improvement of data analysis (image treatments, unattended exposure devices, etc).

**Narrowband filter instruments**

Three multi-channel narrow-band radiometers (NILU-UV6) were installed by INM in the UV-VIS Antarctic stations (see section 1.1.3) in 1999, thanks to the existent agreements of scientific collaboration between INTA, INM, Dirección Nacional del Antártico (DNA/IAA) and Centro Austral de Investigaciones Científicas (CADIC, Argentina). A fourth NILUT-UV-6 runs on a continuous basis at the GAW Izaña Observatory. The NILU-UV6 instruments measure global radiation at five UV channels and PAR. A radiative transfer model is used to calculate the total ozone content, cloud transmittance and the biologically effective UV doses. These instruments are part of the Spanish Antarctic network that has been coordinated in the framework of the joint INTA-INM’s “MAR” (Measurement of Antarctic Radiance for monitoring the ozone layer; REN2000-0245-C02-01) and on-going EGEO (“Estudio de la GEnestis del agujero de Ozono y sus implicaciones sobre la radiación UV”; Reference CGL2004-05419-C02-02ANT, financed both by the R+D National Programme.

The Finnish Meteorological Institute (FMI) is in charge of the NILU radiometers’ quality assurance system performing intercomparisons twice a year with a travelling reference NILU.

The main objective of this network is to provide both long term and near real-time observations of column O3 and UV radiation in order to characterize the polar vortex.

**Spectroradiometers**

UV scans every 20 minutes have been obtained at the Izaña GAW Observatory from the Brewer spectrophotometers since May 1991.

A double spectroradiometer Bentham DM-150, installed in March 1999 at the GAW Izaña Observatory, provides global and diffused UV radiation scans every 15 minutes. This is one of the national UV reference instrument. Since June 2005 is also obtained direct sun UV scans. The Department of the Fundamental Physics of La Laguna University, in collaboration with INM, operates a double Bentham DM-150 spectroradiometer at the Izaña Observatory headquarters (SCO; sea level) in Tenerife. A comparison of the UV and visible spectra obtained from this spectroradiometer with those obtained at the Izaña Observatory (2400 m a.s.l.) have been used to study the connection between UV radiation and radiative properties of the atmospheric aerosols and clouds.

Episodic UV spectra are obtained by the Universities of Barcelona (Bentham DM-300), Valencia (Optronics and LICOR), Valladolid (LICOR) and la Laguna (Bentham and Optronics). Most of the measurements are used in investigations concerning the relationship between aerosol optical depth and spectral UV radiation.

**Calibration activities**

**The WMO/GAW Regional Brewer Calibration Centre for RA-VI region (RBCC-E)**

In November 2003 the WMO/GAW Regional Brewer Calibration Centre for RA-VI region (RBCC-E) was established at Izaña Observatory (IZO) at Tenerife (Canary Islands). The project is also intended to contribute to the GAW Programme in the RA-VI Region as a part of the closer co-
operation between WMO and the European Commission being stated in the Memorandum of Understanding signed by WMO and EC in December 2003.

IZO is located in subtropical region (28°N) on the top of Izaña Mountain (2370 m.a.s.l.) with pristine skies and low ozone variability. This location allows routine absolute calibrations of the references in similar conditions to the Mauna Loa Observatory (MLO) site.

The RBCC-E reference is based on three double Mark-III Brewer spectroradiometers (the IZO triad): a Regional Primary Reference (B157), a Regional Secondary Reference (B185) and a Regional Travelling Reference (B183). The IZO triad is regularly sun calibrated by means of Langley method and by external lamps. The travelling reference ensures reference transference to the WMO-Region VI Brewer network.

Though B157, B183 and B185 are routinely calibrated by Langley plots method, these absolute calibrations are not used for definition of a new calibration scale. The MSC triad is respected as the official reference of the GAW Brewer international scale. The establishment of the IZO triad allows the implementation of a self-sufficient European Brewer calibration system that respects the world scale but works as independent GAW infrastructure. The IZO triad is linked to the world reference MSC triad with yearly calibrations towards the Canadian travelling reference B017. Systematic extraterrestrial constants (ETC) have been obtained by Langley method with B157 from 1998 to 2002. A comparison against ETCs transferred by travelling B017 shows an agreement within 1% in this period. This excellent result means, first of all, that IZO is an excellent site to assure independent absolute sun calibration for the Brewer network, and secondly that the process based on ETC transfer from MSC triad to the world Brewer network through the travelling reference B017, is very accurate.

The function of RBCC-E also allows development and testing of new measurement techniques for the ground Brewer network like zenith, polarimetric, UV or aerosol optical depth measurements at IZO. A dark room and an electronic workshop are available at IZO for accurate fittings and indoors calibration and maintenance of the triad instruments.

**Total ozone calibrations**

The Brewers (#033 and #157) at the Izaña Observatory have been intercompared with the international travelling reference Brewer#17 every year since 1991. The Brewer#17 is routinely calibrated against the World triad (Meteorological Service of Canada). Other Brewers of the network are intercompared and calibrated every two years. Last three intercomparisons were held at the El Arenosillo station in September 1999, September 2001 and September 2003 (see Table 1).

**Spectral UV calibrations**

Spectral UV Quality Control (QC) consists of 50W lamp tests at each station performed every 2 weeks. Spectral UV Quality Assurance (QA) is carried out every year using a portable 1000W lamp calibration system designed by Int'l Ozone Services Inc. (IOS, Canada). Primary standard lamps (NIST traceable) are located at the optical lab of the Izaña Observatory. Before and after the national calibration trip 1000W secondary standard lamps are calibrated against the primary ones.

**UV Broadband instrument calibrations**

A primary reference UV pyranometer, located at the Izaña Observatory, and a secondary portable reference UV pyranometer are kept just for the broadband UV network tests. The primary reference instrument participated in a broadband UV detector intercomparison organised by the LAP (Laboratory of Atmospheric Physics) of the Aristotle University of Thessaloniki (Greece) in September 1999. This intercomparison, carried out within the scope of the COST 713 action on "UV-B forecasting", hosted a total of 33 UV broadband detectors from 14 countries.
Comparisons of these pyranometers with double Brewer and Bentham spectroradiometers have been performed at the Izaña Observatory and at the El Arenosillo station.

Three national UV and visible spectroradiometer intercomparisons were held at the El Arenosillo station (INTA) in September 1999, September 2001 and September 2003, respectively. Solar measurements and lamp calibrations were performed.

RESULTS FROM OBSERVATIONS AND ANALYSIS

A total ozone climatology and trend analysis has been performed by INM for each ozone station in Spain, as well as a comparison with overpass TOMS data.

Annual and diurnal UV index variations have been calculated for each capital of province.

Continuous comparison during the life of the satellite with the ground-based NDSC instruments in Izana has been performed. Up to now only O$_3$ and NO$_2$ columns have been intercompared. BrO measurements comparison will be started during the year 2005.

Scientific results from Observations have been published in SCI papers (see section 4.3).

THEORY, MODELLING, AND OTHER RESEARCH

In accordance with the COST-713 action (“UV-B prediction”) of the European Commission a H+24 forecasting model of UVI for Spain has been implemented by INM. This model has a resolution of 5’x5’ on a geographical domain bounded by 45ºN/15ºW and 25ºN/5ºE. The ozone prediction is based on a regression model, and the UVA-GOA radiative model from Valladolid University is used for UVI calculation. A parameterized cloud modification factor has been also included using the cloud forecasts provided by the ECMWF. Validation of forecasted ozone and UVI is routinely validated using the Brewer and the UV broadband national networks.

The daily maximum forecasted UVI up to 72 h for more than 8000 towns in Spain, as well as the daily variation of UVI under clear skies (up to 48 h) for the province capitals of Spain are reported by internet: http://www.inm.es/web/infmet/predi/ulvip.html

Departments of several universities are carrying out observations and studies regarding solar UV radiation and related atmospheric components. A summary of the activities performed by the Spanish universities is as follows:

- The Department of Optics and Applied Physics of Valladolid University is working on aerosol optical depth (AOD) characterization, including the UV range.
- The Department of Astronomy and Meteorology at Barcelona University has been taking sporadic measurements of UV and visible spectrum for the last nine years using a LI-COR 1800 spectroradiometer and now with a Bentham DM300 spectroradiometer. This group has also measured UV AOD. Work has also been done on simulation modelling using different radiative transfer codes.
- The Department of Thermodynamics at Valencia University is working on the aerosol observations and validating different radiative transfer codes.
- The Department of Applied Thermodynamics at Valencia Polytechnic University has been carrying out continuous measurements of UV with an Eppley radiometer since 1995.
- The Department of Fundamental and Experimental Physics at La Laguna University is working on aerosol characterization and its relationship with spectral UV radiation.
- The Atmospheric Physics Group at Granada University is working on solar radiation, remote sensing and aerosol characterization.
- The Department of Agriculture and Food at La Rioja University has been studying the effects of UV-B radiation on mountain aquatic bryophytes in their natural surroundings and has evaluated their use as bio-indicators.
DISSEMINATION OF RESULTS

Data reporting

The web-based “Iberonesia” data managing interface (www.iberonesia.com) provides near-real time ozone and UV information of the eight instruments of the national Brewer spectrophotometer network. Three Brewers from Portugal and one from Casablanca (Morocco) have been incorporated into this network. The information is stored and validated automatically.

Total ozone daily means are submitted on a daily basis daily to the WMO Northern Hemisphere Daily Ozone Mapping Centre run by the Laboratory of Atmospheric Physics at the Aristotle University of Thessaloniki (Greece) and to the WOUDC.

Evaluated and refined total ozone data from Madrid, Murcia, El Arenosillo, Santa Cruz de Tenerife and Izaña stations are periodically submitted to the WOUDC database.

Concerning global UV, data from each station is submitted daily to the INM’s central database. The UV index (UVI) is disseminated by Internet (www.inm.es/web/infmet/tobsr/ulvio/PRIMERA.html). Ozone soundings form Keflavík/Iceland are posted in real time in the joined IMO-INTA web page: http://grenjandi.vedur.is:8080/ozone/. Information of the ozone&UV Antarctic project, including total column NO 2 for the three stations and ozone vertical profiles over Belgrano project are disseminated through www.inm.es/mar.

<table>
<thead>
<tr>
<th>Brewer Station</th>
<th>Institution</th>
<th>Earliest data / Last updated (\text{WOUDC})</th>
<th>Earliest data / Last updated NDSC</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Coruña</td>
<td>INM</td>
<td>No data</td>
<td>Not NDSC station</td>
</tr>
<tr>
<td>Zaragoza</td>
<td>INM</td>
<td>No data</td>
<td>Not NDSC station</td>
</tr>
<tr>
<td>Madrid</td>
<td>INM</td>
<td>1992-01-01 / 2002-08-15</td>
<td>Not NDSC station</td>
</tr>
<tr>
<td>Murcia</td>
<td>INM</td>
<td>1995-04-01 / 2005-04-18</td>
<td>Not NDSC station</td>
</tr>
<tr>
<td>Santa Cruz Tenerife</td>
<td>INM</td>
<td>1996-01-03 / 2003-06-09</td>
<td>Not NDSC station</td>
</tr>
</tbody>
</table>

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<tr>
<th>Ozonesonde Station</th>
<th>Institution</th>
<th>Earliest data / Last updated (\text{WOUDC})</th>
<th>Earliest data / Last updated NDSC</th>
<th>Earliest data/ Last Updated NILU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Madrid</td>
<td>INM</td>
<td>No Data</td>
<td>Not NDSC</td>
<td></td>
</tr>
<tr>
<td>Belgrano II</td>
<td>INTA</td>
<td>Not NDSC</td>
<td>1999-03.01/ 2005-06-01</td>
<td></td>
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<thead>
<tr>
<th>Station</th>
<th>Institution</th>
<th>Earliest data/ Last updated NDSC. Also at ENVISAT CAL/VAL database</th>
</tr>
</thead>
<tbody>
<tr>
<td>Izaña (UV-VIS)</td>
<td>INTA-INM</td>
<td>2000-01-01 / 2005-06-01</td>
</tr>
<tr>
<td>Izaña (FTIR)</td>
<td>Institut für Meteorologie und Klimaforschung (IMK; Forschungszentrum Karlsruhe, Germany) and INM</td>
<td>1999-02-01 / 2002-12-31</td>
</tr>
</tbody>
</table>
Information to the public

Ozone data over Antarctica are sent to the WMO in almost real time as contribution to the reports on the evolution of the Ozone hole.

The daily maximum forecasted UVI up to 72 h for more than 8000 towns in Spain, as well as the daily variation of UVI under clear skies (up to 48 h) for the province capitals of Spain are reported by internet: http://www.inm.es/web/infmet/predi/ulvip.html.

As part of the activities performed by Spain in the framework of the COST 713 Action “UVB forecasting”, a “UV-Index for the Public” booklet (in Spanish) has been adapted and expanded with some examples for the Canary Islands region by INM. A printed version of this booklet has been published in collaboration with the Dermatology Department at La Laguna University Hospital of Tenerife (HUC) and the pharmaceutical associations of the Canary Islands.

A second printed booklet entitled “Indice UV para la población” was published in June 2002 by the Health Ministry and the Environment Ministry. The booklet can be seen as a web page at www.inm.es/uvi.

 Relevant scientific papers (since 2000)


**Carreño, V., E. Cuevas, and A. Redondas, and V. Cachorro, The INM's Ultraviolet Index forecasting model for Spain, Sixth European Symposium on Stratospheric Ozone, Göteborg, Sweden, September 2 - 6, 2002.**

**Carreño, V., A. Redondas, and E. Cuevas, Validation and new parametrisations in the INM's Ultraviolet Index forecasting model for Spain, Sixth European Symposium on Stratospheric Ozone, Göteborg, Sweden, September 2 - 6, 2002.**


Gil, M., O. Puentedura and M. Yela (2002), Measurements of the BrO column at the Northern Subtropics, Sixth European Symposium on Stratospheric Ozone (Göteborg, Sweden, 2 - 6 September, 2002).


Parrondo M.C., M.Yela, M. Gil and J. Araujo (2004), Fast increase in ozone during the 2002 major warming as observed by ozonesondes located at the vortex splitting point. Proceedings of the Quadrennial Ozone Symposium, IOC, EC, 1-8 June 2004, Kos (EL), IOC, IAMAS (Publs.) – POS/PRO 133.


Schneider, M., T. Blumenstock, M. Chipperfield, F. Hase, W. Kouker, T. Reddmann, R. Ruhnke, E. Cuevas, and H. Fischer (2004), Subtropical trace gas profiles determined by ground-based FTIR spectroscopy at Izaña (28ºN, 16ºW): Five year record, error analysis, and comparison with 3D-CTMs, Atmos. Chem. Phys..


Yela, M., S. Rodriguez, M. Gil, R. Ozu, S. Diaz, M. Chipperfield (2000), Seasonal evolution of NO2 and O3 outside, at the edge, and inside the Antarctic polar vortex comparison with the SLIMCAT model , 2º SPARC General Assembly, Mar de Plata 2000.


PROJECTS AND COLLABORATION

INTA has participated in INOVO (INterhemispheric OCIO Polar VOrtex Variability). This is an intensive campaign to test the new high-resolution spectrograph and carry out measurements of OCIO and study the impact of high reflective surface (snowy surface) on the species retrieved during the winter of 2001 at the polar observatory of Sodankyla, Finland. The instrument was installed at Marambio Base, Antarctica in austral summer 2004. The campaign has been financed by the European Commission through the LAPBIAT infrastructure facility.

INTA and INM have participated in the STREAMER project coordinated by the DLR, Germany. It is a European project from the Earth Observation Programme devoted to forecasting ozone and UV-B in the European sector using the GOME/ESA instrument (and SCIAMACHI/ESA in ENVISAT in the future) and meteorological forecasting. The output is level – 3 products (maps) 24h forecasting of both ozone and UV-B on Internet, available to the public.

INM and INTA have actively participated in recent years in European projects related to ozone and UV research, which have recently finished or are still in progress. They are as follows:

- REVUE (Reconstruction of Vertical Ozone Distribution from Umkehr Estimates), ENV4-CT95-0161
- TRACAS (TRAnsport of Chemical species Across Subtropical tropopause) ENV4-CT97-0546.
- STREAMER (Small Scale Structure Early Warning and Monitoring in Atmospheric Ozone and Related Exposure to UV-B Radiation), ENV4-CT98-0756.
- QUILT (Quantification and Interpretation of Long Term UV-Visible Observations of the stratosphere) EVK2-CT2000-0059. Devoted to improvements of Spectroscopic data products (NO2, O3, BrO, OCIO, IO), Revision of the data sets, Modeling and interpretation, etc.
- QUOBI (Quantitative Understanding of Ozone Losses by Bipolar Investigations) EVK2-CT-2001-00129 (2002-2004): The main objective of the project is to test our quantitative understanding of the chemical mechanisms that destroy ozone in wintertime Arctic stratosphere and springtime Antarctic and to improve the representation of these processes in chemical models of the atmosphere.
- SCOUT-O3 (Stratospheric-Climate Links with Emphasis on the UTLS); SCOUT-O3’s aim is to provide predictions about the evolution of the coupled chemistry/climate system, with emphasis on ozone change in the lower stratosphere and the associated UV and climate impact, to provide vital information for society and policy use.

INM, INTA and the Universities of Barcelona, Valencia, Valladolid and La Laguna have participated in several large coordinated ozone&UV-related projects financed by the National R+D Plan of the Ministry of Science and Technology:

- “Measurement and Modeling for the space-time distribution of the ultraviolet solar irradiance in Spain” (CLI97-0345-C05).

• EGEO (“Estudio de la GEnesis del agujero de Ozono y sus implicaciones sobre la radiación UV”), financed by the Diversity, Earth Sciences and Global Change R+D National Programme; Reference CGL2004-05419-C02-02ANT.

The “Veleta 2002” field campaign was held in July 2002, in the framework of the DEPRUVISE project, financed by the National R+D Plan of the Ministry of Science and Technology. This field campaign has been designed to obtain experimental data of elevation effects on solar ultraviolet irradiance. For this purpose different radiometers and spectroradiometers have been installed on both slopes of the Sierra Nevada Massif. The stations cover from sea level to 3400 m a. s.l. on the top of the Veleta Peak. This information has been used to evaluate the aerosol radiative forcing on the solar UV irradiance. Several groups from the Universities of Granada, Barcelona, Valencia, Valladolid, Malaga and La Laguna, and the INTA and INM have participated in the field campaign.

STREAMER. INTA has participated in a proposal of the European GMES (Global Monitoring the Environment and Security) Programme devoted to the elaboration of H+24 UV and ozone forecasted maps above Europe and research associated to the ozone layer. The new project will focus on operational aspects regarding data management (GIS, Web, etc), climatology of ozone related species and Streamer events on a global scale based on European satellites and 3D modeling. Validation exercises will also be performed to ensure the data and model quality.

Within the framework of the QUILT project, a NDSC intercomparison was held in the winter of 2002/2003 at the polar facility of Andoya, Norway, (68ºN). INTA has participated with its UV-VIS instrument. The purpose was to harmonize results and identify possible causes of discrepancy between instruments. Eleven European Institutes involved in QUILT have participated in this campaign. Unofficial comparison of BrO was carried out as well.

The effects of clouds and the cloud-sea on the spectral UV radiation has been investigated by INM and La Laguna University at the Izaña GAW observatory using radiative models (DISORT/UVSPEC) and in-situ observations made with double spectrophotometers Brewer and Bentham at sea level and 2400 m a.s.l., respectively.

Aerosol optical depth (AOD) at UV range is routinely obtained at Izaña Observatory from the Brewer spectrophotometer triad using the direct sun measurements.

Within the national R+D plan TROMPETA project, a micropulse aerosol lidar (INTA), a plane equipped with ozone and aerosol instruments, and ground-based ozone total column measurements by high quality NDSC (INM and INTA), have been used at the Izaña Observatory facilities (2400 m a.s.l. and sea level) during a heavy Saharan dust storm event was held on July 2005 to find out whether or not the retrieval of satellite operating in backscattering mode such as TOMS and GOME is severely affected by interferences from the absorbent characteristics of mineral aerosols.

INTA and INM contribute to the EU 6th framework programme SCOUT-O3 project (2003-2007) with activities carried out in the subtropical region around the Tenerife Island. O₃, NO₂ BrO measurements will be focus around the UTLS region.

INTA participates in the TASTE project (2003-2004) funded by the ESA for official validation of O₃ and NO₂ in ENVISAT Sciamachy onboard instrument. The project has been extended two more years within the TASTE-II (2005-2006) for a continuous validation during the satellite lifetime.
Spain has endorsed the EU Action COST 723 ("The Role of the Upper Troposphere and Lower Stratosphere in Global Change"; http://www.cost723.org/) with two delegates from INM and INTA.

Dr E Cuevas (INM) is member of the International Ozone Commission (http://ioc.atmos.uiuc.edu/) and Mr A. Redondas (INM) is member of the WMO Ozone Scientific Advisory Group (http://www.wmo.ch/web/arep/gaw/sag.html)

FUTURE PLANS

Cosine response calibration facilities for Brewer and UV broadband radiometers will be implemented at both, El Arenosillo and Izaña facilities during 2006.

The first GAW Regional Brewer Calibration Center-Europe (RBCC-E) intercomparison campaign of Brewer spectrophotometers will be held at the “El Arenosillo” Atmospheric Sounding Station, INTA (Huelva, Spain) from 9 to 18 September 2005.

A joint collaboration of the National Institute for Aerospace Technology (INTA; Spain), The National Meteorological Institute (INM; Spain), the National Meteorological Service (SMN; Argentina) and the “Tierra del Fuego” Government (Argentina) is being managed in order to establish a permanent ozonesonde programme at the Ushuaia GAW station by the end 2005 or early 2006.

A second intensive campaign using an ozone and aerosol instrument-equipped plane, two aerosol lidars and NDSC instruments is planned to be held in Tenerife in July 2006.

NEEDS AND RECOMMENDATIONS

Satellite community should contribute to financing the ground ozone&UV observation system. Space-borne instruments must be calibrated on a continuous basis with reliable ground based instruments.

Monitoring system should pay special attention to Upper Troposphere- Lower Stratosphere (UTLS) region.

Strong efforts should be done by meteorological forecasting models to improve cloud forecasts. This is needed for a more realistic UVI prediction.

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SWITZERLAND

OBSERVATIONAL ACTIVITIES

Column measurements of ozone and other gases/variables relevant to ozone loss

Total ozone is measured regularly at Arosa since 1926. Presently, the measurements are performed with two semi-automated Dobson spectrophotometers (D101 & D062) and three automatic Brewer instruments B040, B072 (Mark II) and B156 (Mark III).

Profile measurements of ozone and other gases/variables relevant to ozone loss

Balloon ozone soundings are measured from the Payerne Aerological Station three times per week since 1968. Until August 2002, Brewer-Mast ozone sondes were used while since September 2002 ECC (ENSCI – 0.5%) sensors are the operational instruments.

The Umkehr ozone profiles are recorded at sunrise and sunset since 1956. Originally, the measurements were manual and since 1989 an automated Dobson (D051) is dedicated to this task. In 1988, the Brewer (B040) Umkehr series have also been started.

Since 2001, ozone profiles (20 – 70 km) are retrieved from the millimetre wave radiometer SOMORA. Located at Payerne, this instrument delivers thirty minutes averaged profiles continuously.

UV measurements

The Swiss Atmospheric Radiation Monitoring programme (CHARM) consisting of 4 stations covering the altitude range of 366 to 3587 m.a.s.l was build up between 1995 and 2000.

The measurements programme consists of:

- **Broadband measurements**: the direct, diffuse and global components of the broad-band erythemal UV-ERY radiation (Solar Light UV-Biometers) are measured,

- **Narrowband filter instruments**: spectral direct irradiances are measured with Precision Filter Radiometers (PFR) at 16 wavelengths in the range 305 nm to 1024 nm.

Besides the direct measurements, the UV index, the AOD at various wavelengths as well as the Integrated Water Vapor (IW) are calculated from those data.

Spectral Brewer UV measurements

At Arosa, since 1994 spectral global UVB measurements are recorded with the Brewer instruments 072 on the range 290 nm – 325 nm. Since 1998, the Brewer Mark III 156 is in operation and it measures the range 286.5 - 363 nm.

Halocarbon measurements at the global GAW station Jungfraujoch

The high Alpine site of Jungfraujoch (3580 m asl) is one of a few stations covering the entire measurement programme of the GAW concerning greenhouse gases and reactive gases.

The measurements of halocarbons are a part of the SOGE – project (System for Observation of Halogenated Greenhouse Gases in Europe) which is related in terms of standard and quality assurance to the world-wide AGAGE programme (Advanced Global Atmospheric Gases Experiment).
Calibration activities

Regular calibration and maintenance are organised for the Arosa Brewers (every year) and Dobsons (every 4 years) traceable to the world standards for each instrument types.

Each ozone sonde is calibrated in the laboratory prior to the sounding.

The CHARM instruments are compared to reference instruments traceable to the world standards.

RESULTS FROM OBSERVATIONS AND ANALYSIS

Payerne ozone soundings: after a homogenization of the sounding series, the trends at different levels have been updated and the hypothesis of a change of trend at the end of the nineties has been tested. In Fig. 1, the long term trend profiles are given for different cases explained in the caption.

Dobson Umkehr profiles: similarly, the Umkehr Arosa dataset have been homogenized and the trend evaluated. In Fig.2, the trend analysis results are reported and compared to other instruments like satellites (SAGE, SBUV) taken from the last WMO trend assessment.

Figure 1: Trend profiles of the homogenized Payerne ozone sounding series. The green diamonds is the results given in the 98-WM trend assessment while the three others correspond to different selection data subsets used in the analysis (see Favaro et al. 2002 below).

Figure 2: Trend analysis of the Arosa Umkehr dataset before and after homogenization. No proxy beside time has been incorporated in the model and the time period considered is 1980-2000. Trend profiles from satellites (SAGE I+II, SBUV) as well as the mean Umkehr trend from the WMO-trend assessment are also reproduced.
The UV dataset measured at the CHARM station Davos has been extended back in time using a reconstruction method based on sunshine duration, snow cover and ozone amount [Lindford, 2005]. As seen in fig. 3, the last decades present an upward tendency compared to the reference period.

For the localisation of potential European halocarbon source regions a trajectory model was used based on the Swiss Alpine Model, aLMo. Results of the temporal development of the emissions for HCFC 141b and HFC 152a, seen with the trajectory statistics, are shown in fig. 4. The estimated European emissions of the now forbidden HCFC 141b have declined. Those of HFC 152a (not restricted by the Montreal-Protocol) have increased (Reimann and al., 2004).
DISSEMINATION OF RESULTS

Data reporting

The ozone data from Arosa, respectively Payerne are regularly deposited at the WODC and at the NDSC data centers. They are also deposited at NILU data center for validation projects and measurements campaigns (Satellites, ECMWF, MATCH).

The radiation data from the CHAR M Payerne station are deposited at the WRM-BSRN data center.

The SOMORA radiometer data are deposited at NDSC and NILU data centres.

Information to the public

The UV forecasts are issued daily during the summer months in many newspapers, on different web sites (public media, national institutions) and at the TV weather presentations. The alerts for high ozone concentration at surface level are also announced when necessary in the same information channels.

Relevant scientific papers


Favaro, G., P. Jeannet and R. Stübi, 2002: Re-evaluation and trend analysis of the Payerne ozone soundings, Veröffentlichung Nr. 63, MeteoSchweiz, Zürich, Switzerland, 63, 99pp


Müller, G., and Viatte, P., 2005: The Swiss contribution to the WMO Global Atmospheric Watch Programme – Achievements of the First Decade and Future Prospects, Veröffentlichung Nr. 70, MeteoSchweiz, Zürich, Switzerland, 70, 112pp.


PROJECTS AND COLLABORATION

Besides of the activities in the framework of the national and international monitoring and research programmes, Switzerland contributes to the international WMO/GAW programme through the following services and cooperations:

- support to the ozone sounding station Nairobi of the Kenyan Meteorological Institute,
- World Optical Depth Research Centre (WORCC) at Physikalisch-Meteorologisches Observatorium / World Radiation Centre (PMOD /WRC) in Davos
- World Calibration Centre (WCC) and Quality Assurance /Science Activity Centre (QA/SAC) for Surface Ozone, carbon monoxide and methane at the Swiss Federal Laboratories for Materials Testing and Research (EMPA) in Dübendorf.
- Support to the Jungfraujoch site which recently reached the status of global GAW station

At the national level, there is an important cooperation between the national Weather and Climate office (MeteoSwiss) and the academic and research institutions. This collaboration organised within a national GAW-CH programme allows to support research projects for the development and improvement of the monitoring programme as well as for the data analysis.

Other participations are related to:
- satellites validations campaigns (ENVISAT, ODIN, AURA …) with the different instruments mentioned above,
- The development of Standard Operating Procedures for ECC ozone sondes,
- Participation to COST EU actions, …

FUTURE PLANS

- Dobson and Brewer total ozone series difference will be further analyzed and the developed transfer functions will be made available for use in the operational measurements at Arosa,
- Update of the Dobson and Brewer Umkehr retrieval algorithm,
- Study of the long term tropospheric ozone series of Payerne and other sites using trajectory analysis,
- Use of the merged soundings and SOMORA ozone profiles to take profit of the high time resolution and high vertical coverage to investigate phenomena such as solar cycle, QBO (Quasi Biannual Oscillation), planetary waves, etc,
- Development of the Brewer data processing to get other parameters like aerosol optical depth (AOD) or the ozone layer effective temperature,
- Developing the capability of measuring the solar irradiance in other spectral bands within the CHARM network,
- Improve the link between the CHARM radiation measurements and future cloud detection systems,
- Integration of the Alpine Surface Radiation Budget (ASRB) network of 11 stations within the Alpine Arc to the radiation monitoring programme,
- WCC, QASAC (EMPA): development and maintenance of the meta-data information system GAWSIS at WMO will be carried on.

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Ozone Observations

Ozone measurements have been made by an ozonesonde instrument at Ankara, Turkey since early 1994 by the Turkish State Meteorological Service. Ankara is located at 32° 53’ (E) Longitude and 39° 57’ (N) Latitude with an altitude of 891 m. Ankara is capital of Turkey and situated in the mid-northern part of the Central Anatolia Region. Ozone observations have been operated in every one or two weeks or sometimes a month since beginning. Therefore, daily measurements are not available. Total ozone column is detected with this operation. It is possible to find vertical ozone distribution, vertical ozone profile, in this way. Up to now, total 246 balloon have been launched and 222 daily total ozone column data have been obtained. The 24 observations could not be performed due to the different reasons such early exploding of the balloon.

The measured ozone data is sent to the ‘World Ozone and Ultraviolet Radiation Data Centre’ (WOUDC) in order to be archived and published. The station number of Ankara is 348 in WOUDC.

The quality of the ozone data obtained from ozonsonde instrument has been evaluated taking into account the Total Ozone Mapping Spectrometer (TOMS) data obtained aboard the Earth Probe Satellite. A preliminary comparison study was made by using the Ankara’s data and the TOMS’ data. Total 86 TOMS’ ozone data for Ankara location was obtained from the NASA Goddard Space Centre, and a correlation was found between the TOMS and the Ankara’s ozononde data. The rather, high correlation coefficient of 0.89 was detected in this study. This result is statistically significant and shows that there is a good agreement between these data set. At the same study, relative errors of the ozononde data were computed based on the TOMS data is reliable. The mean relative error was found as 2.4 percent. All results showed that ozone measurements in Turkey are reliable.

The ozone time series of Ankara was also analysed statistically and looked for trend at the evaluation studies of the Turkey’s ozone data. Any significant trend was detected, no clear decrease or increase. The extreme values in ozone time series were found as 232 DU and 450 DU. The mean total ozone column was computed as 315 DU. This values were very close to the values of documents of WMO and UNEP (The changing ozone layer, Rumen D. Bojkov,1995).

On the other hand, we have some doubt for our ozononde instrument. So, ozononde includes 2 part, transmitter and ozononde. Before every observation it is necessary to calibrate ozononde part of instrument with an ozonizer/test unit. However, maintenance of the current ozonizer/test unit has never been done since beginning.

Ozone Forecast

Turkish State Meteorological Service (TSMS) has given its attention to the ozone forecast for the last one year. Some ozone forecasting models have been evaluated in the Research Department of TSMS. It has been decided to use a statistical regression model originally given by Long et al,( Bull. Am. Met. Soc. Vol.77, 1996). This model uses geopotential height and temperature together for standard pressure levels (500, 100 and 50 hPa) in forecasting total ozone column. Firstly data set including daily ozone, upper atmospheric radiosonde data covering 500 and 100 hPa geopotential heights and 50 hPa temperature measurements obtained. TOMS ozone data was used in that study because of daily ozone data is not available in TSMS. Therefore, estimated ozone data have been obtained only for the period of January 2000 – March 2001.
Estimated and measured ozone data for each day have been compared. It has been found that this model can estimate total ozone column with an about 9 percent relative error. Although estimated data series exhibit an agreement with measured data, some discernible deviations are detected. It has been computed that the 11 percent of estimated data showed excess deviations. All results show that model could be used to forecast total ozone column.

On the other hand a new study has been started to improve ozone forecasting model. In this study the relationships between ozone and upper air meteorological parameters for Ankara, Turkey have been investigated. It was seen that geopotential height of 500 and 100 hpa levels and the temperature thickness of 300 and 200 hpa levels have rather high statistical significant relationship with the ozone. The regression model has been designed with these new parameters. It was seen that the early results of the new upgraded model have better results statistically. The studies on this model have been going on.

**UV-B Observations**

The B band of the ultraviolet radiation has been measured with an UV-B recorder named Model 501 in two one location, Ankara and Antalya (located on southern coast of Turkey and at 54 m. Altitude, 30° 44’ (E) Longitude and 36° 42’ (N) Latitude).

The UV-B observations were started on 3 January 1997 at Ankara, and on 21 May 1997 at Antalya. There is any problem on the UV-B time series of Ankara. However, time series of Antalya has some gaps and missing data. Uv-B recorder hasn’t work in Antalya from August 2003. But this year we are planning to establish new instrument.

UV-B data have never been evaluated climatologically and statistically because of the very short time series.

Although, this year has been started Uv-Index forecasting in Ankara by using Canadian Empirical Model.

**PLANNED STUDIES**

Planned studies for the period of 2005 – 2008 are as follows:

- To have more strong ozone and UV-B network in Turkey with three Spectrometers and twenty UV-B recorders;
- To detect troposferik ozone profile;
- To detect stratospheric ozone profi;
- To product daily ozone forecast routinely;
- To make UV index forecast routinely;
- To analyse time series of the ozone and the UV-B;
- To evaluate effects of the changes in the ozone and UV-B time series on the climate.

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TURKMENISTAN

Monitoring of atmospheric ozone

In Turkmenistan monitoring of atmospheric ozone is accomplished by a National Committee on Hydrometeorology at the Cabinet of Ministers of Turkmenistan (Turkmengidromet). At present continue systematic daily observations of the total amount of the atmospheric ozone at three stations:

Ashgabat (37°57’ N, 58°21’ E, 311.6 m, since 1926)
Repetek (38°34’ N, 63°11’ E, 185 m, since 1983)
Turkmenbashi (40°03’N, 53°0’ E, 82.5 m, since 2002)

The measurements of total ozone amount are done by means of the ozonometer M-124, manufactured in Russia. The ozonometers technically became obsolete, already many years they were not calibrated. Spare and reserve ozonometers for replacement and control are absent. Nevertheless the carried out comparative analysis between the temporary changes in the total ozone amount, obtained using the ozonometers M-124 and by data of Central Aerological Observatory scientific report, gives satisfactory agreement.

Information

The daily averaged data of total ozone amount, obtained at three stations are sent by telegram to Moscow 736 OZONE. Monthly schedules O-3 not later than 3 days of the following month are sent to the Main Geophysical Observatory named Voeikov. Further all data are transferred to the coordinated international network by data exchange of the World Meteorological Organization (WMO). All primary data are stored in the archive of Turkmengidromet.

Studies

Scientific analysis of a change in the total amount of atmospheric ozone in Turkmenistan is conducted by the Scientific and Technical Centre "Climate" of Turkmengidromet. The conducted investigation is directed toward the study of a regional special features of a change in the total ozone amount and their time variations, and also determination of the possible sources responsible for the destruction of ozone layer. The study of changes in the monthly averaged values of the total ozone amount above the territory of Turkmenistan showed that these changes are satisfactorily coordinated with changes of the spectrum of rigid ultraviolet radiation in the phase of high solar activity.

In the last decade an increase of the quantity of industrial objects in Turkmenistan can lead to the growth of the role of anthropogenic factor. Turkmenistan ratifying Viennese convention and Montreal protocol, and also London corrections to the Montreal Protocol had been undertaken the corresponding obligations on the problem solution of the Ozone depleting substances (ODS). Plan of actions is developed on the decrease of pollutants ejection in the atmosphere and on ODS phase-out.

Problems and needs

The contemporary level of investigations requires the presence of new technical equipment, which will permit to carry out the regular control of the content of ozone both in the atmospheric surface layer and at the stratosphere heights.

This is dictated by the fact that decrease of the total ozone amount in the stratosphere leads to an increase of the intensity of UV - rays dangerous for the life, and its increase in the atmospheric surface layer adversely affects on human health and it leads to a drop in the productivity of agricultural crops.
For obtaining more reliable information about the total ozone amount it is necessary to enlarge a network of regular daily observations, also widely use the data, obtained from the satellites. This can be carried out with the aid of the acting stations equipping by the contemporary instruments and opening of new stations with the technical support of international organizations.

In Turkmengidromet there is necessity in training of young specialists with purpose of effective usage of contemporary instruments for measuring the total amount of atmospheric ozone and ultraviolet radiation. It is also necessary to master the new mathematical models, utilized for the evaluation of local variations in the content of ozone and forecast of the ozone layer behaviour, to continue scientific studies for clarification of reasons, which lead to a change of total ozone amount.
UNITED KINGDOM

MONITORING STRATOSPHERIC AND BOUNDARY LAYER OZONE

Defra funds an on-going monitoring programme that records total values of stratospheric ozone at two UK locations. At the end of 2003 the measurements from the Dobson instruments at Camborne Observatory were replaced by a Brewer spectrophotometer in Reading. The UK Met Office continues to make measurements with the Dobson instrument at the Lerwick Observatory in the Shetland Islands. The spectrophotometers are used to record daily values, except when weather conditions prevent values from being recorded and during the winter in Lerwick when the sun is too low in the sky.

The data are processed daily by the local operators and then quality checked and disseminated. A number of checks are performed in order to ensure the integrity of these data, including comparison of daily results with satellite measurements, and the nearest ground-based measurements. Dissemination involves uploading a ‘best daily average’ to a dedicated web page on the internet and issuing the results to the World Ozone and Ultra Violet Data Centre (WOUDC) Real-time Mapping Centre. Monthly data are submitted to the WOUDC for inclusion on their archive.

Days where the processed total ozone is below two standard deviations less than the long-term average mean for that month are designated as ‘low ozone’ events and are reported to the UK government immediately along with additional analysis.

The Reading Brewer 075 instrument (operated by Manchester University) was serviced and calibrated against a reference standard by IOS (International Ozone Services) in April 2004. It is intended to take both Brewer instruments to the first Regional Brewer Calibration Centre-Europe (RBCC-E) intercomparison exercise for the RA IV region at EL Arenosillo Spain in September 2005.

The Dobson spectrophotometer intercomparison, took place at the Regional Dobson Calibration Centre (MOHP), Hohenpeissenberg, Germany from 9th May 2004 to 29th May 2004. This forms part of the World Meteorological Organisation’s QA/QC programme to assure the quality of the measurements and to assess the performance of the instruments. All instruments are carefully maintained and checked monthly.

Manchester University has two ozone lidar instruments; a fixed system for upper troposphere/lower stratosphere, and a trailer-mounted system for boundary layer/lower troposphere. They are both used on a campaign basis to study particular scientific issues. Most of their recent ozone work has been concerned with the boundary layer.

STRATOSPHERIC OZONE RESEARCH

Defra funds a research project that analyses the ozone data collected at Reading and Lerwick. This research focuses on identifying low ozone events, and predicting how the frequency of low ozone events could alter as stratospheric levels change.

The Natural Environment Research Council (NERC) funds the Upper Troposphere/ Lower Stratosphere (UTLS) OZONE Programme, which commenced in 1999 and will continue for 7 years to 2006. The main aim is to improve understanding of the causes of ozone change in the UTLS in the past, present and future. This is a region where ozone has been changing but the causes still remain uncertain. To date, 43 scientific research projects have been funded which cover a wide variety of research topics. These range from transport of trace gases on annual and seasonal timescales, dynamical processes occurring on short-timescales, studies of chemical processes in the atmosphere and the laboratory and modelling studies of chemistry-climate interactions. This research has led to an improved understanding of chemical composition and structure in the UTLS.
region between 6 and 20km and has resulted in 157 refereed publications to date. Results from the Programme have shown, in particular, that interactions between dynamics (meteorology) and chemistry in the atmosphere play an important role in governing the distribution of ozone and other trace gases in the UTLS.

The European Commission (EC) research programmes encourage collaborative projects involving research groups in different countries. The European Ozone Research Co-ordinating Unit (EORCU), which is based at the University of Cambridge was set up in 1989 to coordinate stratospheric ozone research in Europe from both the national research programmes and the European Union research programme. There are now many joint projects between European scientists. Those listed below are coordinated by UK institutions.

The UK Met Office was the coordinator of the EuroSPICE project (Stratospheric Processes and their impacts on Climate and the Environment) which completed in 2003 (other partners were: CNRS-SA, France, CNRS_LMD, France, Finnish Met. Inst., Finland, Free University of Berlin, Germany, University of Reading, UK, University of Buenos Aires, Argentina). The specific aim of the EuroSPICE project was to update the observed stratospheric trends in ozone, surface UV and temperature and simulate those trends using climate models with/without coupled chemistry. The simulations were then used to predict the behaviour of these parameters over the period 2000-2019, determining the likely cause of past stratospheric trends and developing understanding of the impact of stratospheric change.

Imperial College, London coordinated SOLICE (SOLar Impacts on Climate and the Environment) was funded under the 5th FP and completed in March 2003 (other partners were: Free University of Berlin, Germany, University of Oslo, Norway, CNRS-SA, France, University of Thessaloniki, Greece, CCLRC, UK, University of Arizona, USA, Goddard Institute for Space Sciences, USA). Objectives included the assessment of the impact of solar variability on stratospheric ozone, radiative forcing and surface UV using coupled chemistry-climate models and to produce 3-D measures of the solar signal in temperature, geopotential height and ozone over the next solar maximum.

The university of Cambridge coordinate SCENIC (Scenario of Aircraft emissions and impact studies on chemistry and climate), which is part of CORSAIRE a European research cluster used to coordinate stratospheric ozone research (5th FP funding) (other partners were Airbus, France, University of Oslo, Norway, Airbus GmbH, Germany, Centre National de Recherches Meteorologiques (CNRM), France, Deutsches Zentrum fur Luft- und Raumfahrt e.V (DLR), Germany, Office National d'Etudes et de Recherches Aerospatiales (ONERA), France, University of L'Aquila, Italy, Airbus, UK, Centre National de la Recherche Scientifique (CNRS), France). SCENIC is investigating the potential future impact of aviation on atmospheric composition and climate, and how possible environmental impacts may be reduced. These questions are addressed by performing modeling studies and will influence the detailed design and operation of a possible new supersonic fleet. Atmospheric researchers and the aviation community are collaborating closely in SCENIC. Specifically, this work package aims to study the direct impact of supersonic emissions of water vapour and NOx on ozone chemistry and transport in the UTLS, and secondly the feedback of climate change, due to supersonic aircraft emissions, on ozone chemistry and transport.

TROPOSPHERIC OZONE MONITORING AND RESEARCH

Ground-level ozone is recorded hourly at 73 automatic recording stations (52 urban and 19 rural) across the UK.

A number of research programmes both funded by Defra and NERC and looking into the impacts of tropospheric ozone on vegetation and the impact of the global carbon cycle. Research into the impacts of changing tropospheric ozone levels on vegetation has also been funded by Defra.
Tropospheric ozone modelling is carried out at the Met Office as part of the Climate Prediction Programme funded by Defra. Prediction of future climate requires predictions of radiatively-active trace gases such as ozone, and a coupled climate-chemistry model has been developed to fulfil these requirements. Work continues to develop and validate chemical and aerosol aspects of the model. Work is underway to validate the model against ozonesonde (a lightweight, balloon-borne instrument that is mated to a conventional meteorological radiosonde) and other measurements.

Defra also fund a project across a number of UK Universities to develop tropospheric ozone models. Forecasting the formation of ground-level ozone requires the use of sophisticated numerical models to understand the factors affecting its production and subsequent control. The objective of the project is to develop a modelling capability to treat ozone formation (a) on all spatial scales from urban areas at high spatial resolution to the global scale so that ozone production on the regional and global scales is linked and (b) from timescales of hours, to reproduce the diurnal behaviour of ozone to decades so that the influence of climate change can be assessed.

MONITORING OZONE-DEPLETING SUBSTANCES

Defra has provided support for projects that monitor ozone-depleting substances by analysing ground-based measurements at Mace Head (Ireland). Since 1987, high frequency, real time measurements of the principal halocarbons and radiatively active trace gases have been made at Mace Head, Ireland.

Using the Mace Head data and a Lagrangian dispersion model, NAME (Numerical Atmospheric dispersion Modelling Environment), driven by the output from the U.K. Met Office’s Numerical Weather Prediction model it is possible to estimate Northern Hemisphere baseline concentrations for each trace gas and their European and UK emission distributions. This verification work is consistent with good practice guidance issued by the Intergovernmental Panel on Climate Change (IPCC).

MONITORING AND RESEARCH INTO EFFECTS OF INCREASED UV-B RADIATION

Two UV monitoring sites are in operation – there is a green-field site at Reading, and a city site in Manchester. The Reading site spectroradiometer is calibrated on site and has been providing regular measurements since 1993. It provides hourly spectrums between sunrise and sunset in the 280-500nm range. Periodic international comparisons with other UV spectroradiometers have provided consistently good results. The Manchester instrument provides five minute averages in each of five narrow wavebands (305, 313, 320, 340, 380nm). Apart from calibration periods, the instrument has been in continuous operation since 1997, and provides a southern site in the Nordic network of GUV radiometers. The measurement data are submitted to the World Ozone and Ultraviolet Data Centre.

The solar UV index is measured at seven the sites in the UK by the Radiation Protection Division of the Health Protection Agency. The Department of Health provides support for UV monitoring performed by the National Radiological Protection Board (NRPB). The Solar Radiation Monitoring Project at NRPB provides information for the Global Solar UV Index in association with WHO, WMO, UNEP and the International Commission on Non-Ionizing Radiation Protection.

Commitment to future monitoring and research

At this stage Defra has not specified the areas that will receive direct government funding in the future. However, given the high priority of VCV/3 part (d), some research into stratospheric interactions and climate will be included in the contract funded by Defra at the Met Office. Monitoring of a comprehensive range of ODSs will be funded, for at least the next three years, in
line with VCV/3 part (a). The current basic level of ozone monitoring will be maintained, but any expansion of the monitoring activities will depend on budgetary constraints.

NERC are planning to support future ozone research through their UTLS (Upper Troposphere Lower Stratosphere) completing in 2006 www.utls.nerc.ac.uk.

Further information

Details of Defra funded research, including the full reports for scientific contracts, can be accessed from the Defra website at www.defra.gov.uk by following the links to the environment pages.

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UNITED STATES OF AMERICA

OBSERVATIONAL ACTIVITIES

Column Measurements

Ozone

_BUV/SBUV/SBUV-2 Satellite Instrument Series (8 Instruments)_

The Backscatter Ultraviolet (BUV) and Solar Backscatter Ultraviolet (SBUV) instrument series has produced the longest satellite record for column ozone (April 1970 to the present, with a data gap between 1974 and 1978). NOAA plans to continue the SBUV-2 series on its Polar Orbiting Environmental Satellites (POES) through the end of this decade. Data from the NASA Nimbus-7 satellite and the NOAA POES have been recently reprocessed using the SBUV version 8 algorithm developed at NASA to achieve a cohesive data set standardized to Nimbus-7. The algorithm has been optimized for deriving trends, and for deriving accurate total ozone at large solar zenith angles (75° to 88°), since it does simultaneous retrieval of ozone profile and total ozone. The data set consists of monthly average total ozone in 10° latitude bands from January 1979 to December 2004. (NOAA/CPC, NASA)

_Total Ozone Mapping Spectrometer (TOMS) Instrument Series (4 Instruments)_

The TOMS series of instruments has produced daily global maps of column ozone at solar zenith angles up to 84° since November 1978, with a data gap between April 1993 and July 1996. Data recently have been reprocessed using the TOMS version 8 algorithm, which minimizes aerosol effects and performs better at large solar zenith angles, though not as well as SBUV V8. Data quality of EP/TOMS has degraded since 2000 because of instrument problems. Corrections are being developed using SBUV-2. (NASA)

_Ozone Monitoring Instrument (OMI) on the Aura Satellite_

Built with collaboration between the Netherlands and Finland, and operating since August 2004 on the EOS Aura satellite, this hyperspectral imaging spectrometer continues the total column ozone record begun with the Nimbus-7 TOMS instrument. Two different total ozone algorithms are utilized, one based on the TOMS heritage and the other on the GOME/DOAS heritage. The algorithms agree well in cloud-free areas, but vary by up to 10% in cloudy areas and at large solar zenith angles. Lack of sufficient “ground-truth” for conditions where they differ makes the assessment of data quality difficult at the present time. (NASA)

_Dobson Network_

Dobson total column ozone measurements in the U.S. are done through the NOAA/CMDL Cooperative Network at 16 locations, including 10 national sites in the continental U.S. and Hawaii. Five other sites are collaborative international programmes (South Pole, Perth, Lauder, Samoa, OHP). Data are used for satellite validation and determining ozone trends for the WMO/UNEP Ozone Assessments. NASA also supports Dobson measurements within the U.S. under the auspices of the Network for the Detection of Stratospheric Change (NDSC, see Section 1.1.2.3) (NOAA/CMDL, NASA)

_UVB Monitoring and Research Programme (UVMRP)_

Direct-sun column ozone is retrieved by UV Multi-Filter Rotating Shadowband Radiometers (UV-MFRSRs) at 32 U.S. sites, 2 Canadian sites, and 1 New Zealand site within the U. S. Department of Agriculture (USDA) UV Monitoring and Research Programme (UVMRP). (USDA)
Ozone-Relevant Gases and Variables

Total Ozone Mapping Spectrometer (TOMS) Instrument Series (4 Instruments)

The TOMS series of instruments has produced daily global maps of column SO₂ from volcanoes at solar zenith angles up to 84° since November 1978 (data gap between April 1993 and July 1996). Aerosol absorption has a large affect on surface radiation and actinic flux. Hence, a technique has been developed to derive aerosol absorption optical thickness (AAOT) in the UV from TOMS. Globally, AAOT in the UV can vary from nearly zero in clean areas to more than 0.5 in biomass-burning regions and in the presence of desert dust. The uncertainty in the TOMS-derived AAOT is about 0.02. Hence, it can capture most large events. (NASA)

Ozone Monitoring Instrument (OMI) on the Aura Satellite

In addition to its primary focus on column ozone, OMI measures tropospheric columns of aerosols, nitrogen dioxide, and sulphur dioxide. (NASA)

Network for the Detection of Stratospheric Change (NDSC)

This international ground-based remote-sensing network, championed in the U.S. by NASA and NOAA, was formed to provide a consistent, standardized set of long-term measurements of atmospheric trace gases, particles, and physical parameters via a suite of globally distributed sites. While the NDSC maintains its original commitment to monitoring changes in the stratosphere, with an emphasis on the long-term evolution of the ozone layer (its decay, likely stabilization, and expected recovery), its priorities have broadened considerably to encompass the detection of trends in overall atmospheric composition and understanding their impacts on the stratosphere and troposphere, establishing links between climate change and atmospheric composition, calibrating and validating space-based measurements of the atmosphere, supporting process-focused scientific field campaigns, and testing and improving theoretical models of the atmosphere. Through collaborative investigations with scientists at U.S. and foreign institutions, column measurements of numerous atmospheric constituents are measured at NDSC Primary and Complementary Stations. NDSC instruments that are particularly suited for such column measurements include UV/Visible spectrometers for ozone, NO₂, BrO, and OClO; FTIR spectrometers for a wide variety of source and reservoir compounds; and Dobson and Brewer spectrometers for ozone. Additional information on the NDSC is available at http://www.ndsc.ws/. (NASA, NOAA/CMDL)

Profile Measurements

Ozone

BUV/SBUV/SBUV-2 Satellite Instrument Series (8 Instruments)

This instrument series has produced the longest satellite record of ozone in the upper stratosphere (1-30 hPa) from April 1970 to the present, with a data gap between 1974 and 1978 (see Section 1.1.1.1). Data recently have been reprocessed using the SBUV version 8 algorithm developed at NASA. They will be used to derive a cohesive ozone-profile data set suitable for trend determinations. Profile ozone data from the SBUV/2 on the NOAA POES are used as input to NOAA/NCEP’s Global Forecast System. (NOAA/CPC, NASA)

Stratospheric Aerosol Measurement (SAM) and Stratospheric Aerosol and Gas Experiment (SAGE) Instrument Series (4 Instruments)

The SAM/SAGE series of instruments has provided the longest data set on the vertical profile of ozone in the stratosphere. Near-global coverage has been provided on a near-monthly basis for the periods 1979 to 1981 and 1984 to present. The SAGE ozone data are a benchmark for ozone profile trends. Recent improvements in the processing algorithms have substantially reduced ozone retrieval sensitivity to enhanced aerosols by almost a factor of 10. The SAGE II instrument will complete its mission in late September 2005, after more than 21 years of valuable service. (NASA)
Upper Atmosphere Research Satellite (UARS) Instruments

The UARS HALOE instrument has measured profile ozone since September 1991. UARS measurements are scheduled for termination on 8 December 2005. EOS Aura instruments will continue to make most of these measurements (ozone, H₂O, CH₄, NO₂, HCl, and temperature). (NASA)

Polar Ozone and Aerosol Measurement (POAM) Satellite Instrument Series

The POAM solar occultation instruments (POAM II, 1994 to 1996; POAM III, 1998 to present) continue to provide high-latitude (55°N to 71°N and 63°S to 88°S) measurements of ozone from the upper troposphere to the lower mesosphere. Through most of the POAM measurement period, it has been the only satellite instrument to provide continuous, high-vertical-resolution measurements of stratospheric ozone in the ozone hole region. Recently, this data record has been used to show a significant decrease in the amount of ozone loss at the top of the ozone hole in the past four years (2001 to 2004) relative to that observed during the first six POAM measurement years. (DoD/NRL, NASA)

Aura Satellite Instruments

Aura, the third and last of the NASA Earth Observing System (EOS) observatories, was launched on 15 July 2004, and was designed to make comprehensive stratospheric and tropospheric composition measurements from its four instruments, the High-Resolution Dynamics Limb Sounder (HIRDLS), the Microwave Limb Sounder (MLS), the Ozone Monitoring Instrument (OMI), and the Tropospheric Emission Spectrometer (TES). MLS, HIRDLS, and TES each were designed for measuring ozone profiles. MLS was turned on shortly after launch, and has been delivering ozone-profile data for the upper troposphere and stratosphere since that time. After activation, HIRDLS was found to have a blockage in the optical path. However, even with the 80% blockage, measurements at high vertical resolution still can be made at one scan angle, and ozone profile retrievals recently have been demonstrated. Nevertheless, HIRDLS will not have its designed horizontal coverage, nor will it be able to make measurements over the Antarctic. After launch, the TES translator mechanism began to show signs of bearing wear. The instrument was commanded to skip the limb-sounding modes in May 2005, and will not obtain ozone profiles via this mode of operation; however, some ozone profile information may be derived from the nadir measurements. (NASA)

Balloonborne Measurements

NOAA routinely conducts ozonesonde measurements at nine locations. These include five domestic sites (Hawaii, California, Colorado, Alabama, Rhode Island) and four international sites (South Pole, Fiji, Samoa, Galapagos). NASA supports the operations of the Southern Hemisphere Additional Ozonesonde (SHADOZ) network of ozonesonde launches from several locations in the tropics and southern subtropics. This network operates in collaboration with NOAA and numerous international partners. NASA also flies ozonesondes and an ozone photometer as components of near-annual, moderate-scale balloon campaigns. Additional ozone profiles are obtained during such campaigns using a submillimeter/millimeter-wave radiometer, an infrared spectrometer, and a far-infrared spectrometer. (NOAA/CMDL, NASA)

Dobson Umkehr

Profiles are obtained from six automated Dobson instruments using the Umkehr technique (Lauder, Perth, Hawaii, Boulder, OHP, Fairbanks). Through collaboration between NASA and NOAA, a new ozone-profile algorithm has been developed to process Dobson Umkehr data. This algorithm is similar to the SBUV V8 algorithm, and has been optimized for deriving trends. (NOAA/CMDL, NASA)

Network for the Detection of Stratospheric Change (NDSC)

Two of the remote sensing instruments designated as primary components of the NDSC are providing long-term profile measurements of ozone. These are the lidars (which measure in
both the troposphere and stratosphere) and the microwave radiometers (whose retrievals are limited primarily to the stratosphere). Ozonesondes routinely launched at many NDSC stations also provide ozone-profile data. In addition, several of the high-resolution FTIR spectrometers are beginning to yield ozone-profile information. (NASA, NOAA/CMDL)

**Ozone-Relevant Gases and Variables**

**Stratospheric Aerosol Measurement (SAM) and Stratospheric Aerosol and Gas Experiment (SAGE) Instrument Series (4 Instruments)**

The SAM/SAGE series of instruments has provided the longest data set on the vertical profile of aerosols in the stratosphere. Near-global coverage has been provided on a near-monthly basis for the periods 1979 to 1981 and 1984 to present. Recent improvements in the processing algorithms have produced a fully usable water vapour product for the first time. The SAGE II instrument will complete its mission in late September 2005, after more than 21 years of valuable service. (NASA)

**Upper Atmosphere Research Satellite (UARS) Instruments**

The UARS HALOE instrument has measured profile H$_2$O, CH$_4$, NO, NO$_2$, HCl, HF, and temperature since September 1991. UARS measurements are scheduled for termination on 8 December 2005. EOS Aura instruments will continue to make most of these measurements (ozone, H$_2$O, CH$_4$, NO$_2$, HCl, and temperature). The UARS SOLSTICE and SUSIM instruments measure UV light above the atmosphere between 115 and 410 nm, a wavelength range that impacts both the production and loss of ozone. These measurements started in September 1991, and are scheduled for termination in early August 2005. Instruments on the SORCE satellite will continue these measurements. The UARS PEM instrument measures proton and electron flux into the atmosphere. These measurements started in September 1991, and are scheduled for termination in early August 2005. Instruments on the NOAA GOES and POES satellites will continue these measurements. (NASA)

**Polar Ozone and Aerosol Measurement (POAM) Satellite Instrument Series**

The POAM instruments continue to provide high-latitude (55°N to 71°N and 63°S to 88°S) measurements of H$_2$O, NO$_2$, and aerosol extinction from the upper troposphere to the lower mesosphere. POAM measurements indicate that there were fewer polar stratospheric clouds (PSCs) between 2001 and 2004 at these altitudes, suggesting that the reduced ozone loss also observed is primarily the result of a change in meteorology (toward warmer conditions) in the Antarctic stratosphere over the past four winter seasons. (DoD/NRL, NASA)

**Aura Satellite Instruments**

In addition to ozone-profile measurements, the four Aura instruments were designed to provide profile measurements of numerous other atmospheric constituents and parameters in the stratosphere and troposphere. MLS has been delivering profiles of temperature, H$_2$O, ClO, BrO, HCl, OH, HO$_2$, HNO$_3$, HCN, N$_2$O, and CO since the instrument was activated. Despite the optical path blockage, HIRDLS likely will retrieve profiles of temperature, H$_2$O, CH$_4$, N$_2$O, NO$_2$, HNO$_3$, N$_2$O$_5$, CF$_2$Cl, CF$_2$Cl$_2$, CIONO$_2$, and aerosols. Nevertheless, HIRDLS will not have its designed horizontal coverage, nor will it be able to make measurements over the Antarctic. Because of the issues discussed above for TES, no profile data will be obtained via limb scanning; however, some profile information may be derived from the nadir measurements of temperature, CO, H$_2$O, and CH$_4$. (NASA)

**Balloonborne Measurements**

NOAA monitors upper tropospheric and stratospheric water vapour using cryogenic, chilled-mirror hygrometers that are flown in combination with ozonesondes on a biweekly schedule in Boulder, CO, and at Lauder, New Zealand, in collaboration with NIWA. Water-vapour profiles also are obtained on a campaign basis in Indonesia, the Galapagos, and Hawaii. NASA supports the flights of several balloon instruments (primarily on a campaign basis) capable of providing
profile information for numerous atmospheric constituents. *In situ* measuring instruments include a whole-air sampler, gas chromatograph, and TDL and NDIR spectrometers. Over the last decade, near-annual deployments of a NOAA automated gas chromatograph on NASA’s Observations of the Middle Stratosphere (OMS) *in situ* balloon gondola have revealed distinct changes in the 0- to 32-km vertical profiles of ozone-depleting substances (ODSs) and other gases. Flights of remote-sensing instruments (a submillimeter/millimeter wave radiometer, an infrared spectrometer, and a far-infrared spectrometer) also have been conducted on an annual basis. It should be noted that the total column abundance for various atmospheric altitude regions can be derived from the profile data for a particular species. (NOAA/CMDL, NASA)

**Airborne Measurements**

NASA-sponsored airborne campaigns, using both medium- and high-altitude aircraft, have been conducted with NOAA, NSF, and university partnerships, with a focus on satellite validation and scientific study of ozone and climate change. While designed more for process study than for trend determinations, the airborne measurements have provided a unique view of changes in atmospheric composition at various altitudes in response to source forcings. For example, gas chromatographic measurements taken from high-altitude aircraft (ER-2, WB-57F) in the upper troposphere and lower stratosphere since 1991 have established a 14-year record of the amounts of chlorine and bromine entering the stratosphere, and the halogen loading in the lower stratosphere. (NASA, NOAA, NSF)

**Network for the Detection of Stratospheric Change (NDSC)**

Several of the remote sensing instruments designated as primary components of the NDSC provide profile data for a variety of ozone-relevant gases and variables. These include temperature, water vapour and aerosol measurements by lidars, and water vapour measurements by microwave radiometers. Aerosol-backscatter profiles obtained weekly by NOAA in Colorado, Hawaii, and Samoa are able to detect an increase in stratospheric particle surface area resulting from major volcanic eruptions and capable of affecting heterogeneous chemical ozone loss. The NRL ground-based Water Vapour Millimeterwave Spectrometer (WVMS) instruments measure 40- to 80-km water vapour at Lauder, New Zealand (1992 to present); Table Mountain, California (1993 to 1997, 2003 to present); and Mauna Loa, Hawaii (1996 to present). These measurements confirmed and validated the large increase in water vapour observed by the UARS HALOE instrument in the early 1990s, they show that this trend ceased in the mid-90s, and they demonstrate that there has been (at most) a very small (<0.5%) negative (decreasing) trend in upper stratospheric/lower mesospheric water vapour since late 1996. (NASA, NOAA/CMDL, DoD/NRL)

**Ground-Based In Situ Measurement Networks**

Weekly to bi-weekly flask samples are collected at 13 globally distributed sites and are analyzed on three instruments at NOAA/CMDL for a total of ~25 gases, most of which are involved in ozone depletion (including all of the gases regulated under the Montreal Protocol). NASA supports a flask sampling effort conducted by the University of California, Irvine (UCI), under which seasonal sampling is conducted at 40 to 50 sites ranging from 71°N to 47°S. These flask data provide the basis for determining global, tropospheric trends of these gases and for computation of effective equivalent chlorine (EECl) in the atmosphere. (NOAA/CMDL, NASA)

The NASA Advanced Global Atmospheric Gases Experiment (AGAGE) network conducts high-frequency measurements at five globally distributed sites of many of the halocarbons identified as ODSs, and it has the longest continuous observational record for such species, extending back more than 25 years for some CFCs. New advanced instrumentation now permits the monitoring of many of the CFC replacements, thereby enabling a tracking of such chemicals from their first appearance in the atmosphere. Similar instruments maintained at the four NOAA Baseline Observatories (South Pole, Samoa, Mauna Loa, Pt. Barrow) and at a remote, cooperative research site (Niwot Ridge, Colorado), obtain high-frequency measurements (~hourly) of 10 ozone-depleting gases, including all of the major ozone-depleting gases and most of the Group I and II ozone depleters. Measurement and standards intercomparisons between the AGAGE and
NOAA/CMDL networks and with other international collaborators are leading to an improved long-term database for many ozone- and climate-related gases. These measurements also provide independent records for verifying flask analyses and help to understand the processes that contribute to atmospheric variability of these gases. (NOAA/CMDL, NASA)

**UV Irradiance Measurements**

**Broadband Measurements**

**SURFRAD Network**

Seven Surface Radiation Budget Network (SURFRAD) sites operate Yankee Environmental Systems, Inc. (YES) UVB-1 broadband radiometers. The ISIS network of solar measurements includes broadband Solar Light 501 UVB biometers at each of nine sites. Other instrumentation (located at the Table Mountain test facility near Boulder, Colorado) includes a triad of calibration-reference YES UVB-1 broadband radiometers, and two calibration reference Solar Light 501 UVB biometers. Several other broadband UV radiometers also are operated at the Table Mountain site. These include a Scintec UV radiometer, two types of Kipp & Zonen broadband UV radiometers, an EKO UV radiometer, and a Solar Light 501 UVA biometer. (NOAA/SRRB)

**CMDL Network**

Supplemental measurements of UV-B using YES UVB-1 instruments continue at Boulder, Colorado and Mauna Loa, Hawaii, where high-resolution UV spectroradiometers also are operated and can be used to interpret accurately the broadband measurements. (NOAA/CMDL)

**USDA UVB Monitoring and Research Programme (UVMRP)**

Thirty-four YES UVB-1 radiometers are fielded under this programme (see Section 1.1.1.5). (USDA)

**Narrowband Filter Measurements**

**SURFRAD Network**

Currently operating at the Table Mountain test facility in Colorado are a Biospherical Instruments GUV-511 UV radiometer, a Smithsonian 18-channel UV narrow-band radiometer, and two YES UV-MFRSRs. A YES UV-MFRSR soon will be deployed at the Central Ultraviolet Calibration Facility’s High-Altitude Observatory at Niwot Ridge, Colorado. (NOAA/SRRB)

**CMDL Network**

Narrowband radiometers (Biospherical Instruments, GUV, 305 nm, 313 nm, 320 nm, and 380 nm) are used at three sites in Alaska. These sites were established in 1998 and operated for about two years with initial funding, but have been operated in a minimal-maintenance mode since. One site was discontinued in 2003 when it was determined that the combination of on-site support and data communications problems were prohibitive. Initial and subsequent calibrations of the instruments have been performed by the manufacturer. Due to reductions in personnel and funding, since 2001 the instrument calibration schedules have been reduced and adequate quality control has not yet been applied to the data. (NOAA/CMDL)

**USDA UVB Monitoring and Research Programme (UVMRP)**

UV-MFRSRs deployed within this network measure total and diffuse horizontal and direct normal irradiance at 300, 305, 311, 317, 325, 332, and 368 nm with a 2.0-nm bandpass. (USDA)

**NSF UV Monitoring Network**

Biospherical Instruments (BSI) GUV-511 moderate bandwidth multi-channel radiometers are deployed at five of the seven network sites (McMurdo and Palmer Station in Antarctica, San Diego California, Barrow Alaska, and Summit Greenland). A BSI GUV-514 radiometer is deployed at the South Pole. (NSF)
**Spectroradiometer Measurements**

**Total Ozone Mapping Spectrometer (TOMS) Instrument Series**

Data from this series of satellite instruments, originally designed for column ozone retrievals, have been used to produce daily global maps of spectral UVB and UVA since November 1978, with a data gap between April 1993 and July 1996. The data are most useful for tracking weekly and long-term variability of UVB/UVA at ~100-km spatial scales. The data recently have been reprocessed using an improved algorithm. Aerosol absorption (due to soot and mineral dust) and clouds over snow are the largest error sources. The NASA Goddard Space Flight Center (GSFC) and Finnish Meteorological Institute (FMI) are collaborating to develop advanced algorithms that correct these effects. (NASA)

**Ozone Monitoring Instrument (OMI) on the Aura Satellite**

The space-based UVB measurements begun with the TOMS instruments (see Section 1.3.3.1) will continue with OMI. FMI is responsible for producing the UVB product, and is collaborating with NASA GSFC on the algorithm development. (NASA)

**SURFRAD Network**

A high-precision UV spectroradiometer and a UV spectrograph are located at the Table Mountain Test Facility in Colorado under the auspices of this programme. (NOAA/SRRB)

**Network for the Detection of Stratospheric Change (NDSC)**

State-of-the-art, high-resolution spectroradiometric UV observations are conducted as a part of the NDSC at several primary and complementary sites. In particular, U.S. collaboration with NIWA (New Zealand) enables such measurements at Mauna Loa, HI and Boulder, CO. The measurements at Mauna Loa were started in 1995, those in Boulder began in 1998, and they continue to the present. (NOAA/CMDL)

**NSF UV Monitoring Network**

BSI SUV-100 high-resolution scanning spectroradiometers are deployed at all seven network sites (McMurdo Station, Palmer Station, and South Pole Station in Antarctica; San Diego California; Barrow, Alaska; Summit, Greenland; and Ushuaia, Argentina). A BSI SUV-150B spectroradiometer is also deployed at Summit, Greenland. (NSF)

**UV-Net Programme**

Brewer Mark IV spectrometers that measure the spectrum between 290 and 325 nm are deployed at all 21 network sites located in 14 U.S. national parks and 7 urban areas around the U.S. (EPA)

**Calibration Activities**

**BUV/SBUV/SBUV-2 Satellite Instrument Series (8 Instruments)**

To produce recently released V8 data, instruments were carefully cross-calibrated using internal methods. Derived trends are independent of ground-based network and other satellite data. (NOAA/CPC, NASA)

**Total Ozone Mapping Spectrometer (TOMS) Instrument Series (4 Instruments)**

The TOMS instruments have been cross-calibrated against the SBUV instrument series. Thus, the SBUV series provides the calibration, while TOMS provides the coverage. (NASA)
**Ozone Monitoring Instrument (OMI) on the Aura Satellite**

The OMI column ozone dataset released thus far is based on the TOMS V8 algorithm, which has been calibrated against SBUV. Future release, based on the DOAS algorithm, will be independent of SBUV. (NASA)

**Dobson Network**

World Standard Dobson No. 83 is maintained at NOAA/CMDL as part of the World Dobson Calibration Facility, and regularly participates in international intercomparisons of regional and national standards. (NOAA/CMDL)

**Network for the Detection of Stratospheric Change (NDSC)**

Several operational protocols have been developed to insure that NDSC data is of the highest long-term quality as possible within the constraints of measurement technology and retrieval theory at the time the data are taken and analyzed. Validation is a continuing process through which instruments and their associated data analysis methods must be validated before they are accepted in the NDSC and must be continuously monitored throughout their use. Several mobile intercomparators within the various NDSC instrument types exist to assist in such validation. (NASA, NOAA/CMDL)

**Ground-Based In Situ Measurement Networks**

Both the NOAA/CMDL and NASA/AGAGE networks independently develop and maintain highly accurate and precise calibration scales at ppt and ppb levels for the major and minor long-lived ozone-depleting gases. In addition, both networks are developing reliable calibration scales for the short-lived halogen-containing gases that have been introduced as CFC replacements. These new calibration scales support research which addresses the roles of the very short-lived gases that may help explain the apparent imbalance between bromine in the stratosphere and in the troposphere. The International Halocarbons in Air Comparison Experiment (IHALACE) is being supported and should help to form a basis for developing a homogeneous record of halocarbon atmospheric abundances derived from diverse international datasets. (NOAA/CMDL, NASA)

**SURFRAD Network**

The Central Ultraviolet Calibration Facility (CUCF) is located in NOAA's David Skaggs Research Center in Boulder, Colorado. The CUCF calibrates more than 80 UV instruments per year for several U.S. Government agencies and other UV research concerns, both national and international. In addition to laboratory calibrations, the CUCF has developed a portable UV field-calibration system that allows laboratory-grade calibrations to be made at spectroradiometer field sites. The CUCF also produces secondary standards of spectral irradiance that are directly traceable to NIST primary standards. The secondary standards can be calibrated for operation in either the vertical or horizontal orientation. (NOAA/SRRB)

**USDA UVB Monitoring and Research Programme (UVMRP)**

NOAA CUCF lamp calibrations performed in horizontal and vertical position using NIST traceable 1000-W halogen lamps are used to calibrate 48 USDA UV-MFRSRs and 46 UVB-1 broadband. A U-1000 1.0-m double Jobin Yvon with 0.1-nm resolution and 10^-10 out-of-band rejection is used as a reference spectroradiometer to transfer lamp calibration to a broadband triad. The UV-MFRSR radiometer spectral response and its angular response (critical for direct beam retrieval) are measured. The Langley calibration method is employed to provide additional absolute calibration of UV-MFRSRs and to track radiometric stability in situ. (USDA)

**UV-Net Programme**

Collocating ultraviolet radiation (UVR) monitors of different types (e.g., multifilter and broadband instruments) is important for determining changing surface levels and their cause. This supports instrument calibration and data comparison among networks, and allows continuous data
collection should an instrument temporarily fail. Currently, only three network Brewers are colocated with other UVR monitors. The Table Mountain Test Facility in Colorado is host to numerous UVR instruments for data intercomparison and calibration. While some instruments remain there for years, others are transported there annually for intercomparison and calibration. The EPA Brewer in Big Bend National Park is 47 kilometres from USDA’s climatological station. The instruments at Big Bend have been compared since February 1997. Other UVR monitor colocations operate at Bondville, Illinois and Fort Peck, Montana with SURFRAD and USDA monitors. (EPA)

RESULTS FROM OBSERVATIONS AND ANALYSIS

Ozone

Trend Analyses

Merged Satellite Datasets

Merged total and profile ozone data sets have been created using V8 TOMS and SBUV data adjusted to a common calibration. The V8 data already have been cross-calibrated, so additional adjustments are small (no adjustments to the profile data). These data sets are easily accessible, and convenient for users who do not wish to analyze multiple instrument data sets. (NASA)

Ozonesonde Data

An analysis of Northern Hemisphere ozonesonde data utilizing a statistical model that includes the 1979 to 1996 trend, the trend-change in 1996, plus ancillary variables of solar cycle (f10.7), QBO, and AO/AAO has been completed. (NOAA/CPC)

A comparative analysis of South Pole and Syowa ozonesonde data going back to the 1960s has been completed. (NOAA/AL, NOAA/CMDL)

Ozone Depletion

Statistical analysis of the merged TOMS/SBUV profile ozone data set from 1979 to 1997 shows the largest negative trends in the upper stratosphere at high latitudes (-7% per decade at 47.5°S and -6% per decade at 47.5°N), and less negative trends in the tropics and below 30 hPa (-1 to -3% per decade), which is in general agreement with previous profile trend estimates from satellite and ground-based records. This total and profile ozone information also has been used extensively to study the morphology of the anomalous 2002 ozone hole. Further, these data have been used in a correlative study relating the Southern Hemisphere polar vortex to the depletion levels of springtime total ozone at high northern latitudes. An intriguing, though unexplained, connection was found between the strength and interannual variability of these features (correlation coefficient > 0.7). Ultimately, understanding these interactions will improve our ability to predict future ozone changes. (NASA)

Antarctic Ozone Hole

Since approximately 1997, the underlying trend of Antarctic ozone (i.e., the trend after removal of the effect of natural variability in vortex temperatures) has been zero. This cessation of the downward trend in ozone is consistently seen at 60°S to 70°S in TOMS total ozone columns, SAGE/HALOE stratospheric columns, ozonesonde ozone columns at Syowa (69°S), and Dobson total column measurements at 65°S and 69°S. The size of the Antarctic ozone hole is primarily controlled by inorganic chlorine and bromine levels (effective equivalent stratospheric chlorine, EESC), and secondarily controlled by the temperature of the Antarctic vortex collar. Fits of the ozone-hole size to temperature and chlorine and bromine levels suggest that the ozone-hole size actually may be decreasing at a very slow rate. This slow decrease is masked by the large natural variability of the Antarctic stratosphere. (NASA)
Ozone Recovery

TOMS/SBUV and Dobson/Brewer total ozone columns and SAGE/HALOE columns above 18 km altitude show that ozone between 60ºN and 70ºS has ceased to decline since approximately 1997. Results derived from the worldwide network of ozonesonde measurements provide similar evidence. Such behaviour appears to be associated with the levelling off and gradual decline in stratospheric halogen loading. In contrast, most of the increase in ozone abundance between the tropopause and 18 km is inferred to be due to transport changes. The increase in this layer can explain approximately half of the post-1997 changes in the total ozone column. (NOAA/CMDL, NOAA/SRRB, NASA).

Ozone Maps

Daily maps of total ozone and monthly total ozone anomalies are being produced, as well as routine updates of the SBUV-2 total ozone change utilizing a statistical model that includes the 1979 to 1996 trend, the trend-change in 1996, plus ancillary variables of solar variation (f10.7), QBO, and AO/AAO. In addition, twice-yearly (Northern and Southern Hemisphere) winter summaries of selected indicators of stratospheric climate are generated. (NOAA/CPC)

Ozone-Related Gases and Variables

Trend Analyses

Upper Atmosphere Research Satellite (UARS) Data

UARS measurements have been used to analyze atmospheric trends in ozone, H2O, CH4, NOx (NO+NO2), HCl, HF, and temperature. These measurements also have been used to quantify UV light variations at wavelengths from 115 to 410 nm over the 27-day solar rotation period and an 11-year solar cycle period. (NASA)

Ozone-Related Chemistry

Effects of Large Solar Proton Events (SPEs)

Several satellite instruments (UARS HALOE; NOAA 14 and 16 SBUV-2; POAM III; Aura MLS; Envisat GOMOS, MIPAS, and SCIAMACHY; and Odin OSIRIS) have shown evidence in recent years of solar-particle-caused changes in polar atmospheric constituents. These include large enhancements in mesospheric NOx (>50 ppbv) as a result of the extremely large SPEs in solar cycle 23, significant stratospheric NOx enhancements (>20 ppbv) in the winter/fall polar regions after extremely large SPEs in July 2000 and October 2003, and polar mesospheric enhancements of OH (>50%) as a result of the SPE in January 2005. Very large polar mesospheric ozone decreases (>70%) were measured only during the SPEs of July 2000 and October 2003. Modest, but significant, polar upper stratospheric ozone decreases (>10%) persisted after the SPEs of October 2003. Total ozone decreases were computed to be less than 2%. (NASA)

Rate of Ozone Destruction by HOx

The rate of odd hydrogen production via the reactions of electronically excited oxygen atoms, O¹(D), produced via photolysis of ozone, has been quantified. These data reduce the uncertainty in the computed rates of OH production and ozone destruction via HOx catalytic cycles. (NOAA/AL)

Chemical Reservoirs

New measurements of the formation rate for HO2NO2, a reservoir for HOx and NOx species, have been made at temperatures below 250K. The new results have a significant effect on model calculations of HO2NO2 formation. (NASA)
The reactivity of \( \text{HO}_2\text{NO}_2 \), has been further elucidated by new measurements of its reaction rate coefficients; absorption cross-sections in the UV, visible, and near-IR; and the quantum yields for the dissociation. These results have led to an improved quantification of the calculated rates of ozone destruction. (NOAA/AL)

Research at the Jet Propulsion Laboratory (JPL) has focused on the rates and mechanisms of several important reactions that control the ozone budget. Rate constants for the \( \text{OH} + \text{NO}_2 \) reaction, which produces the HNO\(_3\) reservoir for odd hydrogen and odd nitrogen radicals in the lower stratosphere, have been remeasured with higher accuracy and sensitivity than previously possible. These new results predict a smaller HNO\(_3\) formation rate. New studies in halogen oxide chemistry related to polar ozone depletion have improved the understanding of the chemistry of the ClO dimer (ClOOCl), a key intermediate in ozone destruction cycles. Finally, the photochemical mechanism for the oxidation of a key bromine-containing compound, bromoform, has been elucidated. Such information will assist in the understanding of the stratospheric bromine budget. (NASA)

**Polar Stratospheric Clouds (PSCs)**

*Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) Validation*

SAGE III PSC data for the 2002-2003 Arctic winter have been used by to validate PSC sightings and thermodynamic-type classifications of the PSCs observed for that season by the MIPAS instrument on the Envisat platform. (NASA)

*Coupling of Satellite and Aircraft Data*

An analysis of SAGE III 1022-nm extinction versus the 1022-nm/449-nm extinction ratio has enabled the discrimination of PSCs in mixtures of background aerosol with very few large NAT particles, such as the NAT “rocks” observed *in situ* during the SAGE III Ozone Loss and Validation Experiment (SOLVE) airborne campaign. Thus, SAGE III can provide systematic observations of these clouds, which would greatly improve current understanding of how they form and lead to stratospheric denitrification and prolonged ozone destruction. (NASA)

*SPARC PSC Assessment*

SAGE III data will be a focus of the recently initiated SPARC PSC Assessment, which aims to bridge significant gaps that still exist in our knowledge of PSCs. These gaps are primarily in our understanding of solid PSC particle formation, limiting our ability to represent PSCs and their chemical effects in global models and to predict how these might differ in the stratosphere of the future. (NASA)

**Stratospheric Ozone - Climate Connection**

*Antarctic Ozone and Climate*

Recent observational analyses have added to our understanding of the ways stratospheric ozone depletion and tropospheric climate are linked. Specifically, an examination of the Antarctic stratospheric ozone and tropospheric climate during the period from 1979 through 2002 has been used to show that stratospheric variability is an important driver of surface climate variability. (NOAA/AL)

*Aerosol Effects*

Biomass-burning aerosol particles have been observed in the lower stratosphere. The ability of such species to be transported to the stratosphere can impact the chemistry and climate of this region. (NOAA/AL)

*Ozone-Relevant Gases*

A new precise and accurate method for measuring HCl and ClONO\(_2\) in the upper troposphere and lower stratosphere from aircraft platforms using chemical ionization mass
spectrometry has been demonstrated. Use of this methodology in the winter polar stratospheric vortices during periods of rapid ozone destruction will help better quantify and understand ozone destruction processes. The measurements of HCl, in particular, have been used to quantify the amount of stratospheric ozone in the upper troposphere. Expanded use of this method will lead to improved quantification of ozone transport from the stratosphere to the troposphere and the budget of stratospheric ozone. (NOAA/AL)

Oceanic Gas Fluxes

Data from seven research cruises in the past decade have allowed refinement of the atmospheric lifetime of methyl bromide and an improved understanding of the budget of this gas. The cruises provided the only widespread, combined atmospheric and ocean surface measurements of very short-lived gases to date. The most recent cruises took place in 2001 and 2004. (NOAA/CMDL)

UV

UV Trends

SURFRAD Network

Work has been initiated with the Colorado State University (CSU) UVB group to analyze some of the stations in their network for trends in solar UV irradiance. Three radiative transfer models in the UV are being run to compare to spectral direct normal and diffuse horizontal irradiance measurements made with the State University of New York (SUNY) at Albany UV rotating shadowband spectroradiometer on clear days. (NOAA/SRRB)

USDA UVB Monitoring and Research Programme (UVMRP)

Analysis of nine years of broadband data indicates no statistically significant trend in UVB. The difficulty in detecting the expected upward trend in UVB is due to calibration uncertainties, radiometric sensitivity drift, year-to-year variability due to changes in cloud cover, ozone, aerosols, albedo, etc. Improved quantification of these variables is essential for any trends analysis. (USDA)

The variation of ground-level UV irradiance with latitude, season, and elevation revealed by the UVB-1 broadband meter is broadly consistent with theoretical expectations. The large annual cycle in monthly integrated broadband UV irradiance usually peaks in July. During summer, lengthening duration of daylight with latitude poleward counteracts the increase in solar zenith angle at a fixed local time, providing a weaker latitudinal gradient in UV irradiance than at other times of the year. Under this circumstance, localized atmospheric conditions such as cloudiness and limited visibility can have a substantial influence on the differences in radiation levels between sites. (USDA)

UV Forecasts and Exposure

UV Alert System

NOAA/CPC is producing UV forecasts for the U.S., and is developing a UV Alert system with the EPA. The UV Alert system is designed to advise the public when UV levels are unusually high and represent an elevated risk to human health. The UV Alert system consists of a graphical map displaying the daily UV Alert areas, as well as additional information included in the EPA’s UV Index ZIP Code look-up web page and via the EPA’s AIRNow EnviroFlash e-mail notification system. The criteria for a UV Alert are that the noontime UV Index must be at least a 6 and must be 2 standard deviations above the daily climatology. (NOAA/CPC, EPA)

Effects of UVB Exposure

A major limitation in predicting the impacts of UVB irradiance on humans, plant leaves and flowers, and aquatic organisms is the difficulty in estimating exposure. An analysis of the spatial variability in the daily exposure to narrowband 300- and 368-nm and broadband 290- to 315-nm
(UVB) solar radiation between 12 paired locations in the USDA UVB Climate Network over two summer growing seasons has been completed. The spatial correlation of the UVB, 300- and 368-nm daily exposures between locations was approximately 0.7 to 0.8 for spacing distances of 100 km. The 300-nm daily exposure was typically more highly correlated between locations than the 368-nm daily exposure. (USDA)

THEORY, MODELING, AND OTHER RESEARCH

Ozone

Theory, Modelling, and Analysis

Model Comparisons

SBUV-2 total ozone data have been compared with 2-D Chemical Transport Models (CTMs) from the University of Illinois and GSFC. In addition, mechanisms to improve the ozone data assimilation within the NWS Global Forecast System are being developed. This includes the SBUV-2 data, as well as the data that may be available operationally from the NASA Aura satellite (e.g., OMI and HIRDLS) and the GOME2 instrument from METOP. (NOAA/CPC)

Multi-Fractal Analysis

Statistical multi-fractal analysis was used to produce a correlation between the rate of ozone photodissociation and the intermittency of temperature in the Arctic lower stratosphere, with potential implications for radiative transfer, turbulent dynamics, and chemistry. (NOAA/AL)

Photochemical Ozone Loss

The Match technique has been applied to five years of Antarctic data from POAM III, using trajectories obtained from the ECMWF, UKMO, and NCEP meteorological analyses for studying photochemical ozone loss. The results show that the Match ozone loss rates are sensitive to the choice of meteorological analysis. In late August and early September, when ozone loss rates peak near the South Pole, the ECMWF trajectories generally yield lower loss rates than those obtained with the UKMO and NCEP analyses. These differences are important because the NCEP- and UKMO-derived POAM loss rates are significantly higher than model results (using upper limit values for BrO<sub>x</sub> and ClO<sub>x</sub> and JPL 2002 kinetics), while ECMWF results show no significant measurement/model deficit. Because of its higher temporal and spatial resolution, it is reasonable to conclude that the ECMWF results may be more accurate. (DoD/NRL)

A recent modelling analysis suggests that the underestimation of the chemical loss of polar ozone by past photochemical model simulations may be due to two factors: 1) the presence in the atmosphere of much higher levels of bromine than is commonly assumed, due to a significant stratospheric influence of the decomposition products from very short-lived biogenic bromocarbons; and 2) the significantly faster photolysis of the ClO dimer than calculated using recommended cross-sections. It appears that models may provide more accurate simulations of seasonal and long-term ozone depletion due to a greater influence of chemical reactions involving bromine, and that the Montreal Protocol and its amendments are having the desired effect on ozone levels throughout the world. (NASA)

Ozone Forecasts

The Navy Operational Global Atmospheric Prediction System (NOGAPS) is being extended into the stratosphere and mesosphere for the development of an ozone forecast capability. The extended model (NOGAPS-ALPHA) was shown to provide reliable short-range stratospheric ozone forecasts during the second SAGE III Ozone Loss and Validation Experiment (SOLVE-II) campaign. (DoD/NRL)
Interannual Variability

In a study of ozone interannual variability, the GSFC 2-D model was forced with observed wind fields from NCEP and ECMWF global analyses over the period from 1970 to the present. By including the dynamical forcing, the 2-D model resolved most of the observed total ozone variability in time and latitude. Long-term 2-D model simulations with realistic dynamics will enhance understanding of past and predicted ozone change, and can be run using minimal computer resources and time. (NASA)

Decadal Analyses and Simulations

Several multi-decadal integrations of the GSFC 3-D CTM from 1975 to 2025 have been completed. The model includes observed and predicted changes in chlorine and bromine source gases, solar UV radiation, and volcanic aerosols (past only). Model transport is driven by winds from a general circulation model (GCM). To assess the influence of various factors on ozone, the model has been run with chlorine source gas fixed at 1979 levels and without volcanic aerosols. The model output is analyzed using the same statistical approach applied to observations. The ozone response to chlorine is found to be insensitive to interannual variability in time series longer than 25 years. Analysis of the simulations with and without volcanic aerosols suggests that current statistical techniques are unable to accurately separate the volcanic signal from interannual variability in ozone. (NASA)

A chemistry-climate coupled model has been developed and is currently being tested at GSFC. This model is being used to produce 20-year ‘time slice’ simulations with fixed trace-gas boundary conditions and a 150-year integration to study interactions between ozone, water vapour, other greenhouse gases, and climate. (NASA)

Total and profile ozone data from the NOAA 16 SBUV/2 satellite are used in a near-real-time ozone assimilation system at the GSFC GMAO. Data are combined with CTM ozone forecasts to produce global 3-D ozone estimates. Because of its coverage and longevity, SBUV data are commonly used in ozone and meteorological assimilation systems. Tests using MLS and OMI data from Aura in the assimilation system indicate better representation of total and stratospheric ozone using these data. (NASA)

TOMS total ozone is commonly used with a source of stratospheric profile ozone to estimate total column tropospheric ozone. Various methods have been used to construct long-term records of tropospheric ozone, particularly in the tropics. These records have been used in a series of variability and transport studies. (NASA)

Ozone-Related Gases and Variables

Validation Studies

Ground-Based Measurements

A ground-based programme for aerosols and trace gases has produced new results related to NO2 daily and diurnal variation and aerosol UV absorption. The results will be used for OMI validation and for climate studies. (NASA)

Actinic Flux Measurements

The National Center for Atmospheric Research (NCAR) CCD actinic flux spectroradiometer (CAFS) is being deployed on NASA airborne field experiments. The measurements are being used to determine ozone-column abundances above and below the aircraft for the validation of OMI data. (NSF, NOAA/SRRB)
**Environmental Properties of Atmospheric Gases**

**CFC Substitutes**

Laboratory studies of the atmospheric lifetimes and environmental fates of many CFC substitutes have been conducted, thereby permitting an evaluation of their “ozone friendliness.” These results provide important input parameters for model calculations of the future vulnerability of the ozone layer, and are used together with industrial production-and-use information to analyze the growth of such chemicals in the atmosphere. (NOAA/AL, NASA)

**Oceanic Gas Lifetimes**

The partial lifetimes with respect to oceanic loss for more than 90 halogenated gases have been determined using a simple, coupled, ocean-atmosphere box model and the COADS data set for sea-surface temperature and wind speed. (NOAA/CMDL)

**UV**

**UV Instrumentation**

The temperature dependence of the Brewer UV spectrometer has been studied in order to improve the quality of data for UV trends. (NOAA/SRRB)

**UV Effects**

The UVMRP supports research studying UVB effects on plants and ecosystems. Numerous publications document the results of these studies. (USDA)

**DISSEMINATION OF RESULTS**

**Data Reporting**

**Ozone**

**TOMS and SBUV Series**

In June 2004, a 2-DVD set containing the entire TOMS V8 data set was released. The data cover the period from November 1978 through August 2003. Similarly, a DVD containing SBUV V8 ozone profile data was released. Data are from Nimbus 7 (1978 to 1993), NOAA 9 (1985 to 1998), NOAA 11 (1988 to 2001) and NOAA 16 (2000 to 2003). The Goddard Earth Sciences (GES) Data and Information Services Center (DISC) routinely distributes the data. (NASA)

**POAM Data**

Data from the POAM instrument is available via ftp at ftp://poamb.nrl.navy.mil/pub/poam3/ and also is submitted to the NASA Langley Distributed Active Archive Center (DAAC). (DoD/NRL)

**OMI Data**

TOMS-compatible total ozone data produced from OMI since September 2004 are available from the GSFC DAAC at http://daac.gsfc.nasa.gov/. Total ozone data produced using a DOAS algorithm will be available by the end of 2005. (NASA)

**Umkehr Data**

Dobson Umkehr data processed using an SBUV-like algorithm are available at http://www.srrb.noaa.gov/research/umkehr/. (NOAA/SRRB, NASA)
World Ozone and Ultraviolet Radiation Data Center (WOUDC)

Total ozone, Umkehr, and ozonesonde data are reported to the WOUDC from U.S. Government agencies and institutions. Ozone data from sites that are part of the NDSC and the SHADOZ network are available from the programme web sites (http://www.ndsc.ws/ and http://croc.gsfc.nasa.gov/shadoz/, respectively), and also are imported to WOUDC. (NOAA, NASA).

Maps

All daily SBUV/2 total ozone map analyses are available as images in png format on the Internet. The raw data from the SBUV/2 are available from NESDIS. Additionally, the total ozone analysis and forecast fields out to five days from the NCEP GFS are presented via a web page. (NOAA/CPC)

Assessments

2006 WMO/UNEP Scientific Assessment of Ozone Depletion

The latest assessment, mandated under the provisions of the Montreal Protocol, is underway and is expected to provide the Parties with the information in support of future decision-making. (NOAA, NASA)

Arctic Climate Impacts Assessment (ACIA)

Chapter 3: Ozone and Ultraviolet Radiation was completed for the latest ACIA. (NOAA/SRRB)

Ozone-Related Gases and Variables

TOMS Aerosol Data

A preliminary dataset of AAOT in the UV derived from TOMS data can be obtained from torres@tparty.gsfc.nasa.gov. Public release of the data is planned for June 2006. (NASA)

Ozone-Depleting Substance Data

Long-term data from the NOAA/CMDL network are updated every six months on the NOAA/CMDL website (http://www.cmdl.noaa.gov/) and submitted annually to the World Data Centre and to the World Data Center for Atmospheric Trace Gases at the Carbon Dioxide Information Analysis Data Center (CDIAC). Data from field missions (firm-air studies, ocean flux studies), previously posted only upon publication, now are posted shortly after the field missions. Data on very short-lived gases from seven research cruises over the world’s oceans are posted and available for use on the NOAA/CMDL website. (NOAA/CMDL)

Long-term data from the NASA/AGAGE network are reviewed on a semi-annual basis by the Science Team, and are archived every six months with CDIAC. Data from the UCI flask-sampling network are archived similarly. (NASA)

UV Data

SURFRAD Network Data

UV data from the SURFRAD Network are available on the NOAA/SRRB website (http://www.srrb.noaa.gov/). (NOAA/SRRB)

USDA UVB Monitoring and Research Programme (UVMRP)

UVB-1 broadband data and UV-MFRSR data from this network are regularly submitted to the WOUDC. (USDA)
Information to the Public

Ozone

TOMS and OMI Data

Near-real-time ozone data from Earth Probe TOMS and from the OMI instrument on Aura are routinely distributed via the TOMS web site (http://toms.gsfc.nasa.gov/). Data from TOMS are usually available with 12 hours; data from OMI within 2 days. The site provides online access to TOMS data back to 1978. While used mostly by scientists, educators and students also use the site extensively. An Ozone Hole Watch web site is being developed to provide a single site for anyone interested in the Antarctic ozone hole. (NASA)

Merged TOMS/SBUV Total and Profile Ozone Data

Merged TOMS/SBUV total and profile ozone data sets are available on the Internet (http://hyperion.gsfc.nasa.gov/Data_services/merged/index.html). (NASA)

UV

Forecasts

Noontime UV forecasts are made available to the public via several formats. One is a text bulletin for 58 cities for the U.S. The other is a gridded field that is made available via the NOAA/CPC and NOAA/NCEP ftp sites. (NOAA/CPC)

Advisories

The primary UVR advisory in the United States is the UV Index, operated jointly by NOAA and EPA. Currently, the UV Index computer model processes total global ozone satellite measurements, a rough cloud correction factor, and elevation to predict daily UVR levels on the ground and the resulting danger to human health. This model assumes zero pollution levels. UV Index reports are available in local newspapers and on television weather reports. The EPA also issues a UV Alert when the UV Index is predicted to have a high sun-exposure level and is unusually intense for the time of year. UV Alert notices can be found at EPA’s SunWise web site (http://www.epa.gov/sunwise/uvindex.html), in local newspapers, and on television weather reports. (EPA)

Ozone-Depleting Gas Index

An ozone-depleting gas index (ODGI), based on Effective Equivalent Chlorine (EECI) measured globally in the NOAA/CMDL network, is being implemented. EECI is indexed to 1 on 1 January 1994, when it reached its maximum value. (NOAA/CMDL)

Relevant Scientific Papers

Ozone


Weatherhead, E. C., A. Tanskanen, and A. Stevermer, Chapter Three: Ozone and ultraviolet radiation, in Arctic Climate Impacts Assessment (ACIA), 2004.


Ozone-Relevant Gases and Variables


**UV**


**PROJECTS AND COLLABORATION**

**NOAA/CMDL**

The Dobson and ozonesonde measurements are included in the WMO Global Atmosphere Watch (GAW) and in the NDSC. Significant collaboration with federal agencies (NASA, DoE) and universities (University of Colorado, Harvard, Princeton, Humboldt State University, etc.) is maintained through both global monitoring and field missions.

**NOAA/CPC**

Activities include participation in several initiatives of Stratospheric Processes and their Relation to Climate (SPARC), i.e., stratospheric temperatures, ozone, UV, climate change; collaboration with the EPA on the UV Index and, recently, the UV Alert system; collaboration with NASA in ozone monitoring, calibration of the SBUV/2 instruments, and dynamical processes
influencing ozone changes; collaboration with the surface radiation monitoring efforts of NOAA/OAR and USDA-CSU for the validation of UV forecasts and NCEP GFS surface radiation products, and the NDSC Data Host Facility.

NOAA/SRRB

The CUCF is designated by a Memorandum of Understanding to be the national UV calibration facility by agreement among the following organizations: NOAA, USDA, EPA, NASA, National Institute of Standards and Technology (NIST), NSF, National Biological Service, and the Smithsonian Institution. The CUCF compared secondary standards of irradiance with the Joint Research Centre’s European Union UV Calibration Centre’s (ECUV) ultraviolet spectral irradiance scale in Ispra, Italy. The CUCF’s irradiance scale is directly traceable to the NIST spectral irradiance scale, while the ECUV’s irradiance scale is traceable to that of the German national standards laboratory, Physikalisch-Technische Bundesanstalt (PTB).

NASA

NASA collaborates extensively with several NOAA laboratories (AL, CMDL, CPC, SRRB) in all areas of ozone and UV research, including space-based, airborne, balloonborne, and ground-based measurements, as well as in various modelling and analysis activities. NASA often supports research activities within these laboratories in the aforementioned areas. The NDSC, which is championed by NASA and NOAA within the U.S., is a major contributor to WMO’s Global Ozone Observing System (GO3OS) within the frame of its Global Atmosphere Watch (GAW) Programme.

NASA is closely collaborating with KNMI (Netherlands) and FMI (Finland) on processing data from the Aura OMI instrument. Though NASA and KNMI are developing independent algorithms using TOMS and GOME heritage, respectively, the results are being compared carefully to assess the strengths and weaknesses of each algorithm.

USDA

USDA is actively collaborating with the NASA TOMS and AERONET groups on aerosol absorption using UV-MFRSR and Cimel instruments. USDA researchers are funded for participation in the NSF MIRAGE Mexico City air quality study scheduled for February/March 2006. Collaborations also exist with DoE for providing aerosol optical depths and column ozone data. Agency personnel participated in the Norwegian filter radiometer intercomparison held in Oslo in May 2005.

FUTURE PLANS

Ozone

*Column Ozone from Dobson/ Brewer Zenith-Sky Measurements*

The operational zenith-sky total ozone algorithm for Dobson and Brewer instruments is based on empirically derived tables. NASA has developed a TOMS-like algorithm to process these data, which has the potential to substantially improve data quality. There are plans, subject to availability of funds, to process all historical zenith-sky data using this algorithm. (NASA)

*Brewer Umkehr Retrievals*

An Umkehr retrieval capability similar to that developed for the Dobson instrument is being developed for the Brewer spectrometer. (NOAA/SRRB, NASA)

*TOMS Data Reprocessing*

TOMS data likely will be reprocessed before the 2008 Quadrennial Ozone Symposium, based on lessons learned by comparing TOMS with SBUV, GOME, SCIAMACHY, and OMI. (NASA)
**Ozonesondes**

A new ozonesonde programme has been established under the auspices of the NASA/SHADOZ programme in Costa Rica. Ozonesonde launches at Summit, Greenland will begin in collaboration with the NSF in late 2005. (NOAA/CMDL)

**Dynamical Forcings**

An examination of the statistical relationship of tropospheric forcings (e.g., AO/AAO, tropopause pressure, etc.) to changes in total ozone and layer ozone will be undertaken. (NOAA/CPC)

**Ozone-Relevant Gases/Variables**

Improvements in sampling and analysis efficiency have enabled weekly vertical profiles of ~25 trace gases at numerous sites in the lower troposphere. Expansion of this network across North America will aid considerably in source attribution of new and old, short- and long-lived ODSs. Current and future measurement campaigns include multiple deployments of a new gas chromatograph (GC) aboard the Altair uninhabited aerial vehicle (UAV) and the operation of this same instrument onboard a Learjet in Brazil. Plans also include continued monitoring of ODSs from the NASA WB-57F high-altitude aircraft and the NASA OMS balloon gondola. Additional sampling of firn air is scheduled for Greenland as part of an overall firn and ice sampling effort to take place during the International Polar Year. These records continue to improve our understanding of the natural contributions of ODSs. Development and operation of an airborne 6-channel GCMS/ECD that measures approximately 20 important atmospheric trace gases whose changing burdens impact air quality, climate change, and stratospheric/tropospheric ozone will continue. (NOAA/CMDL)

Several aircraft, balloon, and ground-based measurement campaigns are in the planning and near-implementation stages. These campaigns, planned for bases within the U.S. and the subtropics, will provide important validation data for ozone and ozone- and climate-related trace gases and parameters for Aura and other satellite sensors. They also will address high-priority science questions associated with atmospheric ozone chemistry and transport. (NASA)

**UV**

**UV Index Forecast**

An algorithm enhancement will be operational beginning Fall 2005. Features of this enhancement are global coverage, hourly forecasts up to and beyond 72 hours, better cloud transmission estimates, more realistic aerosol depictions, and realistic increases over snow-covered surfaces. Forecasts will be generated on 0.5-degree grids and made available on NCEP’s ftp site. (NOAA/CPC)

**Brewer Network**

An interagency agreement is being negotiated for CUCF to operate a six-station network of Brewer spectroradiometers using instruments from the EPA network that closed in 2004. The primary emphasis will be on the effects of aerosols and clouds on UV radiation, but routine retrievals of ozone, ozone profiles from Umkehr, aerosol optical depth, and nitrogen dioxide also will be attempted. It is expected that the collaboration with the CSU UVB group will lead to further work with the data in their network. It also should be possible to improve on the current methods used to retrieve column ozone, which could lead to improvements in aerosol UV optical-depth retrievals below 368 nm. (NOAA/SRRB, EPA)

**USDA UVB Monitoring and Research Programme (UVMRP)**

A new site planned for Houston, TX, and the development of real-time data streams will be attempted within the network. New interagency collaborations will include participation in the NSF MIRAGE air-quality study in Mexico City (February/March 2006), and the generation of aerosol atmospheric corrections for a NASA/USGS invasive-species study. (USDA)
NEEDS AND RECOMMENDATIONS

Ozone

Column Ozone

Column ozone data produced by satellite and ground-based instruments agree well in cloud-free conditions and at solar zenith angles less than 70º. However, the data quality of all measuring systems degrade under cloudy conditions and at large solar zenith angles, with differences of 10% or larger. Given the need for accurate ozone trends in the polar regions, it is important to improve the quality of ground-based data in these regions, and to focus future calibration and data intercomparison efforts accordingly. (NASA)

Profile Ozone

There is a vast amount of unprocessed Brewer Umkehr data residing in the archives. A concerted effort should be made to process these data using a common Dobson/Brewer algorithm, which is necessary for trend studies. (NASA)

The only currently planned U.S. space-based ozone-monitoring instrument in the post-Aura era will be the NPOESS OMPS instrument, a limb scattering measurement with very little heritage. In order to provide a calibration source for OMPS so that the data will be of sufficient quality for scientific studies and trend analysis, consideration should be given to adding a simple solar occultation instrument to NPOESS. (DoD/NRL)

Ozone-Relevant Gases and Variables

Aerosol Absorption Optical Thickness (AAOT)

There are currently no operational ground-based instruments that provide AAOT in UV. AAOT from the AERONET network is limited to wavelengths longer than 440 nm. NASA has improved a long-standing technique to derive AAOT in UV by combining measurements from AERONET and UV Shadowband radiometers. Efforts to utilize this methodology for deriving AAOT in the UV should be implemented. (NASA)

Ozone- and Climate-Related Trace-Gas Measurements

There is a need to maintain and expand the existing in situ networks, both geographically and with improved instrumentation. Current workforce limitations prevent the development and propagation of gas standards on as rapid a schedule as required by these networks to keep up with the increasing number of new chemicals of scientific interest. In addition, expanded efforts are needed for data analysis as more and more chemicals are being measured. (NASA, NOAA/CMDL)

UV

Geographical Measurement Coverage

UV monitoring in the tropics is very limited. Relatively inexpensive broadband UV instruments could be set up easily at installations launching ozonesondes (e.g., SHADOZ) in the tropical region. Such efforts should be coordinated with the NDSC. In this way, UV at the surface under aerosols/pollution can be linked with the ozone profiles measured by the ozonesondes and ground-based profiling instruments. (NOAA/CPC)

Only seven of the EPA Brewers are currently deployed in or near densely populated areas. Satellite-derived UVR is less reliable for urban locations, because satellite instruments do not adequately characterize pollutants at ground level. Because of the deficiency of current urban UVR data, health researchers conducting local studies are sometimes making their own UVR measurements as needed, with instruments that are often not easily compared with those from any of the existing UVR networks. Thus, better ground-level measurements collected in locations close to air-quality monitors are required. Finally, many sites have data gaps and inconsistencies. Only
a limited number of ground-based sites provide historically continuous UV records. More analyses of available data and improved calibration could fill gaps in coverage. (EPA)

**Calibration and Validation**

The WMO has requested that the CUCF become the WMO centre for UV calibrations. However, funding for this within and outside NOAA has yet to be identified. Efforts to accomplish this should continue. (NOAA/SRRB)

It is now well established that the ratio of UVB and UVA can be predicted accurately under both clear and cloudy conditions wherever quality column ozone data exist. Since total ozone measurements currently are being made globally with very high accuracy and precision by satellite and ground-based instruments, UVB levels can be ascertained, often more accurately than they can be directly measured, if UVA levels are known. However, the causes of UVA variability are poorly understood (clouds, NO₂, aerosols), and satellite and ground-based estimates of UVA show poor correlation in the absence of ancillary data. Future measurements and intercomparisons should focus on this issue. (NASA)

**Effects Research**

Although the effects of UV exposure drive UV monitoring activities, only limited resources historically have been targeted towards UVB effects research. Expansion of UVMRP activities in this critical area is needed at a multi-agency level. (USDA)

**Acronyms and Abbreviations**

<table>
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<tr>
<th>Acronym</th>
<th>Definition</th>
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<tbody>
<tr>
<td>AAOT</td>
<td>aerosol absorption optical thickness</td>
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<tr>
<td>ACIA</td>
<td>Arctic Climate Impacts Assessment</td>
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<tr>
<td>AERONET</td>
<td>Aerosol Robotic Network</td>
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<tr>
<td>AGAGE</td>
<td>Advanced Global Atmospheric Gases Experiment</td>
</tr>
<tr>
<td>AL</td>
<td>Aeronomy Laboratory (NOAA, U.S.)</td>
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<tr>
<td>AO/AAO</td>
<td>Arctic/Antarctic oscillation</td>
</tr>
<tr>
<td>BSI</td>
<td>Biospherical Instruments</td>
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<td>BUV</td>
<td>Backscatter Ultraviolet</td>
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<tr>
<td>CAFS</td>
<td>CCD Actinic Flux Spectroradiometer</td>
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<tr>
<td>CCD</td>
<td>charge-coupled device</td>
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<tr>
<td>CDIAC</td>
<td>Carbon Dioxide Information Analysis Data Center</td>
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<td>CFC</td>
<td>chlorofluorocarbon</td>
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<tr>
<td>CMDL</td>
<td>Climate Monitoring and Diagnostics Laboratory (NOAA, U.S.)</td>
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<tr>
<td>COADS</td>
<td>Comprehensive Ocean-Atmosphere Data Set</td>
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<td>CPC</td>
<td>Climate Prediction Center (NOAA, U.S.)</td>
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<td>CSU</td>
<td>Colorado State University (United States)</td>
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<tr>
<td>CTMs</td>
<td>chemical transport models</td>
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<td>CUCF</td>
<td>Central Ultraviolet Calibration Facility</td>
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<tr>
<td>DAAC</td>
<td>Distributed Active Archive Center (NASA Langley, U.S.)</td>
</tr>
<tr>
<td>DISC</td>
<td>Data and Information Services Center (NASA Goddard, U.S.)</td>
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<tr>
<td>DoD</td>
<td>Department of Defense (United States)</td>
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<tr>
<td>DoE</td>
<td>Department of Energy (United States)</td>
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<tr>
<td>DOAS</td>
<td>Differential Optical Absorption Spectroscopy</td>
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<tr>
<td>ECD</td>
<td>electron capture detector</td>
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<tr>
<td>ECMWF</td>
<td>European Centre for Medium-Range Weather Forecasts (United Kingdom)</td>
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<tr>
<td>ECUV</td>
<td>European UV Calibration Center</td>
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<tr>
<td>EECI</td>
<td>effective equivalent chlorine</td>
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<tr>
<td>EESC</td>
<td>effective equivalent stratospheric chlorine</td>
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<td>EOS</td>
<td>Earth Observing System</td>
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<td>EP</td>
<td>Earth Probe</td>
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<tr>
<td>EPA</td>
<td>Environmental Protection Agency (United States)</td>
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<tr>
<td>FMI</td>
<td>Finnish Meteorological Institute (Finland)</td>
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<tr>
<td>Acronym</td>
<td>Description</td>
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<tr>
<td>FTIR</td>
<td>Fourier transform infrared</td>
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<td>GAW</td>
<td>Global Atmosphere Watch</td>
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<tr>
<td>GC</td>
<td>Gas Chromatograph</td>
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<tr>
<td>GCM</td>
<td>general circulation model</td>
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<tr>
<td>GCMS</td>
<td>Gas Chromatography Mass Spectrometry</td>
</tr>
<tr>
<td>GES</td>
<td>Goddard Earth Sciences</td>
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<tr>
<td>GFS</td>
<td>Global Forecast System</td>
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<tr>
<td>GMAO</td>
<td>Global Modeling Assimilation Office (NASA Goddard, U.S.)</td>
</tr>
<tr>
<td>GOES</td>
<td>Geostationary Operational Environmental Satellite</td>
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<tr>
<td>GO3OS</td>
<td>Global Ozone Observing System (WMO)</td>
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<tr>
<td>GOME</td>
<td>Global Ozone Monitoring Experiment</td>
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<tr>
<td>GOMOS</td>
<td>Global Ozone Monitoring by Occultation of Stars</td>
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<tr>
<td>GSFC</td>
<td>Goddard Space Flight Center (NASA, U.S.)</td>
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<tr>
<td>HALOE</td>
<td>Halogen Occultation Experiment</td>
</tr>
<tr>
<td>HIRDLS</td>
<td>High-Resolution Dynamics Limb Sounder</td>
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<tr>
<td>IHALACE</td>
<td>International Halocarbons in Air Comparison Experiment</td>
</tr>
<tr>
<td>JPL</td>
<td>Jet Propulsion Laboratory (United States)</td>
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<tr>
<td>KNMI</td>
<td>Koninklijk Nederlands Meteorologisch Instituut (The Netherlands)</td>
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<tr>
<td>MFRSRs</td>
<td>Multi-Filter Rotating Shadowband Radiometers</td>
</tr>
<tr>
<td>MIPAS</td>
<td>Michelson Interferometer for Passive Atmospheric Sounding</td>
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<tr>
<td>MIRAGE</td>
<td>Megacity Impacts on Regional and Global Environments</td>
</tr>
<tr>
<td>MLS</td>
<td>Microwave Limb Sounder</td>
</tr>
<tr>
<td>NASA</td>
<td>National Aeronautics and Space Administration (United States)</td>
</tr>
<tr>
<td>NAT</td>
<td>nitric acid trihydrate</td>
</tr>
<tr>
<td>NCAR</td>
<td>National Center for Atmospheric Research (United States)</td>
</tr>
<tr>
<td>NCEP</td>
<td>National Centers for Environmental Prediction (NOAA, U.S.)</td>
</tr>
<tr>
<td>NDIR</td>
<td>non-dispersive infrared</td>
</tr>
<tr>
<td>NDSC</td>
<td>Network for the Detection of Stratospheric Change</td>
</tr>
<tr>
<td>NESDIS</td>
<td>National Environmental Satellite, Data, and Information Service (NOAA, U.S.)</td>
</tr>
<tr>
<td>NIST</td>
<td>National Institute of Standards and Technology (United States)</td>
</tr>
<tr>
<td>NIWA</td>
<td>National Institute of Water and Atmospheric Research (New Zealand)</td>
</tr>
<tr>
<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration (United States)</td>
</tr>
<tr>
<td>NOGAPS</td>
<td>Navy Operational Global Atmospheric Prediction System</td>
</tr>
<tr>
<td>NPOESS</td>
<td>National Polar-Orbiting Operational Environmental Satellite System</td>
</tr>
<tr>
<td>NRL</td>
<td>Naval Research Laboratory (United States)</td>
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<tr>
<td>NSF</td>
<td>National Science Foundation (United States)</td>
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<tr>
<td>NWS</td>
<td>National Weather Service (NOAA, U.S.)</td>
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<tr>
<td>ODSi</td>
<td>ozone-depleting gas index</td>
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<tr>
<td>ODSs</td>
<td>ozone-depleting substances</td>
</tr>
<tr>
<td>OHP</td>
<td>Observatoire de Haute-Provence (France)</td>
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<tr>
<td>OMI</td>
<td>Ozone Monitoring Instrument</td>
</tr>
<tr>
<td>OMPS</td>
<td>Ozone Mapping and Profiler Suite (NPOESS)</td>
</tr>
<tr>
<td>OMS</td>
<td>Observations of the Middle Stratosphere</td>
</tr>
<tr>
<td>OSIRIS</td>
<td>Optical Spectrograph and Infrared Imaging System</td>
</tr>
<tr>
<td>PEM</td>
<td>Particle Environment Monitor</td>
</tr>
<tr>
<td>POAM</td>
<td>Polar Ozone and Aerosol Measurement</td>
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<tr>
<td>POES</td>
<td>Polar Orbiting Environmental Satellites</td>
</tr>
<tr>
<td>PSCs</td>
<td>polar stratospheric clouds</td>
</tr>
<tr>
<td>PTB</td>
<td>Physikalisch-Technische Bundesanstalt (Germany)</td>
</tr>
<tr>
<td>QBO</td>
<td>quasi-biennial oscillation</td>
</tr>
<tr>
<td>SAGE</td>
<td>Stratospheric Aerosol and Gas Experiment</td>
</tr>
<tr>
<td>SAM</td>
<td>Stratospheric Aerosol Measurement</td>
</tr>
<tr>
<td>SBUV</td>
<td>Solar Backscatter Ultraviolet</td>
</tr>
<tr>
<td>SCIAMACHY</td>
<td>Scanning Imaging Absorption Spectrometer for Atmospheric Cartography</td>
</tr>
<tr>
<td>SHADOZ</td>
<td>Southern Hemisphere Additional Ozoneonde (Network)</td>
</tr>
<tr>
<td>SOLSTICE</td>
<td>Solar Stellar Irradiance Comparison Experiment</td>
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<td>SOLVE</td>
<td>SAGE III Ozone Loss and Validation Experiment</td>
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<td>SORCE</td>
<td>Solar Radiation and Climate Experiment</td>
</tr>
<tr>
<td>SPARC</td>
<td>Stratospheric Processes and Their Role in Climate</td>
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<tr>
<td>Acronym</td>
<td>Description</td>
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<tr>
<td>SPEs</td>
<td>solar proton events</td>
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<tr>
<td>SRRB</td>
<td>Surface Radiation Research Branch (NOAA, U.S.)</td>
</tr>
<tr>
<td>SUNY</td>
<td>State University of New York (United States)</td>
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<tr>
<td>SURFRAD</td>
<td>Surface Radiation Budget Network (NOAA, U.S.)</td>
</tr>
<tr>
<td>SUSIM</td>
<td>Solar Ultraviolet Spectral Irradiance Monitor</td>
</tr>
<tr>
<td>TDL</td>
<td>tunable diode laser</td>
</tr>
<tr>
<td>TES</td>
<td>Tropospheric Emission Spectrometer</td>
</tr>
<tr>
<td>TOMS</td>
<td>Total Ozone Mapping Spectrometer</td>
</tr>
<tr>
<td>UARS</td>
<td>Upper Atmosphere Research Satellite</td>
</tr>
<tr>
<td>UAV</td>
<td>uninhabited aerial vehicle</td>
</tr>
<tr>
<td>UCI</td>
<td>University of California, Irvine (United States)</td>
</tr>
<tr>
<td>UKMO</td>
<td>United Kingdom Meteorological Office</td>
</tr>
<tr>
<td>UNEP</td>
<td>United Nations Environment Programme</td>
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<tr>
<td>USDA</td>
<td>U. S. Department of Agriculture (United States)</td>
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<tr>
<td>USGS</td>
<td>U. S. Geological Survey (United States)</td>
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<tr>
<td>UV</td>
<td>ultraviolet</td>
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<tr>
<td>UVMRP</td>
<td>UV Monitoring and Research Programme</td>
</tr>
<tr>
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<td>World Meteorological Organization</td>
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<td>WOUDC</td>
<td>World Ozone and Ultraviolet Radiation Data Centre (Canada)</td>
</tr>
<tr>
<td>WVMS</td>
<td>Water Vapor Millimeterwave Spectrometer</td>
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<tr>
<td>YES</td>
<td>Yankee Environmental Services, Inc.</td>
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UZBEKISTAN

Ozone Monitoring

In Uzbekistan the monitoring of the total ozone content (TOC) and its surface concentrations is carried out by the Service of the Environment Monitoring at the Centre of Hydrometeorological Service at the Cabinet of Ministers of the Republic of Uzbekistan (Uzgidromet).

Currently, the regular daily observations of the total stratosphere ozone content are being conducted at two stations – Tashkent (37.1°N, 69.2°E, 478 m a.s.l.) and Termez (37.1°N, 67.2°E, 311m a.s.l.).

Both stations operate since 1989. At Kumbel and Abramov glacier stations the observations were ceased because of the equipment failure and absence of financing for its restoration.

The observations of the total ozone content are being made with the filtering ozone measuring М-124 device designed by Guschin P. (manufactured in Russian). Because of financial difficulties this device did not undergone calibration, but nevertheless, as it was confirmed by the Central Aerological Observatory (CAO) (Dolgoprudny town, Moscow region, Russia) the data on the stratospheric ozone content measured at Tashkent station, are highly compatible with satellite data.

Systematic observations on tropospheric ozone and other trace gases (CO₂, CO, NO, NO₂ and others) are being continued in all big cities of Uzbekistan. Samples are being taken 2 times a day – in the morning and midday, since April till October. The concentration of tropospheric ozone is made by photometric method based on the displacement of iodine by ozone when it is adsorbed by the solution of potassium iodide. The extracted iodine is estimated by the spectrophotometric measurement of the adsorption spectrum by the iodine ions with the wavelength of 352 nm.

According to the data of systematic observations the mean annual ozone concentration in surface layer in Tashkent in summer exceeds MAC (Maximum Admissible Concentration) from 1.3 to 3 times which corresponds 39-69 µg/m³. The mean daily MAC for Uzbekistan is 30 µg/m³. The highest tropospheric ozone content is recorded in Bekabad (2-3 MAC) and Chirchik (3-3.7 MAC) which is caused by the increased level of the atmospheric pollution with the ozone precursors. Every year the increase of the ozone concentration in surface layer is recorded since May to September, while in October the ozone content is slightly lower. The data of observations are being published in the yearly reviews on atmospheric pollution. In case of the increase ozone concentrations the information is being transferred to the relevant departments of the State Committee on Environment Protection following the pattern of the information exchange adopted in the Republic of Uzbekistan.

Information

The mean daily data on the stratospheric ozone content are transferred one time per month from Tashkent station to the Voeikov’s Main Geophysical Observatory (MGO) (Saint-Petersburg, Russia) for the further generalization and transfer to the World Centre of Ozone Data in Toronto (Canada). The results of the regular daily measurements of TOC are being transferred to the Central Aerological Observatory (CAO) (Dolgoprudny town, Moscow region, Russia) for the inclusion of this information to the international framework of the data exchange.
During winter period (December – March) a similar information is transferred 3 times a week to the University in Tessaloniki (Greece).

Information received from Termez station is being used for scientific studies. All primary information is stored in archive of Uzgidromet of the Republic of Uzbekistan.

At present the data base on stratospheric and surface (tropospheric) ozone is built up. The daily 2-times a day measurements of the surface ozone content in Almalyk (1992-2000), Tashkent (1991-2000), Chirchik (1992-1999), Fergana (1994-2000) cities and measurements of TOC over Tashkent measured by the surface methods and from satellites put the basis for such data base. The concentration of the surface ozone content was measured at 07am and 13pm of the local solar time by the known method and is expressed in \( \mu g/m^3 \). As it is known the concentration of TOC is measured daily in Dobson units.

The values of ozone (O\(_3\)) measured in stratosphere and in surface layer are presented in PC readable form. The software designed for the archive data manipulation are written and debugged.

### Scientific studies on the stratospheric and tropospheric ozone

Scientific and experimental studies related to the investigation of the current state of stratospheric and atmospheric ozone in the Republic of Uzbekistan are carried out at the Research Hydrometeorological Institute of Uzgidromet at the Laboratory of Ozonosphere and Ionosphere Studies and at the Department of Studies and Forecasting of the Environment Pollution.

The conducted studies are aimed to the solution of the following tasks:

- to analyze the available information by the results of parallel measurements of stratospheric and tropospheric ozone to reveal their relationship, evaluation of the stratospheric ozone effect on the surface ozone concentration;
- to study the possible mechanisms of the ozone transfer from stratosphere to troposphere;
- to find out the main mechanisms of the ozone formation in the polluted atmosphere of the urbanized territories and the role of precursors;
- to develop regional models of the ozone formation, of its spatial-time distribution, flow in the conditions of rough orography and arid climate;
- to analyze the state of the measuring network of tropospheric and stratospheric ozone, work out a programme for the measuring network updating;
- to work out a methodology for the evaluation of the zone effect on the surface vegetation; to carry out experimental studies of the surface ozone concentrations on the localities between the settlements; elaboration of standard for the atmospheric pollution by ozone for the surface vegetation.

### Main results

As it was mentioned before, for I, II point the data base was built up by the results of measurements of stratospheric and tropospheric ozone and precursors of the ozone formation. Statistical analysis of the obtained information allowed revealing the relationships between the surface and stratospheric ozone and Wolf numbers. The reference days when stratospheric ozone has undergone the extreme variations were found out. The method of the epoch’s superposition in relation to the reference dates was applied to the Wolf’ numbers. Thus, the situation on the Sun when stratospheric ozone has undergone an extreme sudden increase or decrease of concentrations was defined. On Figure 1 the upper curve corresponds to the positive sudden increase of TOC, while the lower one – to the extreme sudden decrease of TOC values. Table 1 presents the statistical parameters of the both groups along the columns. Despite the substantial discrepancy of statistic data the positive extreme increase of TOC values follow the enhancement of the solar activity while the minimum value of the ozone layer density in stratosphere...
corresponds the lower spot number on the Solar disk. The both processes are about 24 h ahead the phenomena in stratosphere. The obtained result does not contradict the theoretical outlook on the nature of stratospheric ozone formation.

Let’s consider now the surface ozone and try to derive the relationship between the surface ozone and, consequently, the flow of the solar UV-rays. The mean annual values of the Wolf’s numbers and the averaged $O_3$ values measured at Tashkent, Chirchik, Almalyk, Angren, Bekabad and Fergana stations were used. Figure 2 presents the correlation of these parameters. The density of the average monthly ozone values over the region is inversely proportional to the Wolf’s numbers and, consequently, to the flow of UV-rays. If this is right, then it is rather difficult to suppose that the surface ozone component is formed, mainly due to photochemical reactions in the polluted atmosphere.

In the course of investigation of the assessment of the tropospheric ozone effect onto the surface vegetation the important results were obtained.

The results of the conducted studies have revealed the possible negative effect of the nitrogen and ozone oxides on physiology of the vegetation cell. The existence of the manifested inverse relationship between the concentration of photosynthesis pigments and $NO_3^-$ content in vegetation fibers was detected. In this case $NO_3^-$ is the precursor of the ozone formation in the polluted atmosphere.

The studies on the ozone effect on the surface vegetation carried out at the Department of Investigations and forecasting of the Environment Pollution of NIGMI enabled to set up the ecological standard for annual plants - EcoMAC $\mu g/m^3 = 0,061 \mu g/m^3$, MACad (average daily)$= 0,029 \mu g/m^3$ at departmental level.
Upper curve – reference values were selected by maximum TOC.
Lower curve – reference values were selected by minimum TOC.

Figure 1: Averaged variations of the Wolf's numbers in relation to reference dates.
Table 1: Main statistics of the Wolf’s number groups.

<table>
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<tr>
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<th>W-grouping in relation to TOC maximum values</th>
<th>W-grouping in relation to TOC minimum values</th>
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<tr>
<td></td>
<td>-2</td>
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<tr>
<td>Mean value</td>
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<td>Ahead in days</td>
<td>Reference data</td>
<td>Delay in days</td>
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</tbody>
</table>
Figure 2: Comparison of the average annual Wolf’s number with the average of average monthly values by 6 stations of the region in 1992-2000 y.
Problems and needs of the ozone monitoring

The current level of scientific investigations implies the availability of the update equipment and instrumentation. However, under the present circumstances the instrumentation base does not meet the current needs. The filter ozone meters M-124 which are in use at the ozone monitoring stations of Uzbekistan are obsolete and out of date, besides they were not calibrated during many years and need to be calibrated. The last calibration of instruments was made in 1993. It is needed to have at least one Dobbson or Bruger spectrophotometer for the calibration of the network ozone meters.

For getting more comprehensive and reliable information on TOC it is required to extend the network of the regular daily observations which can be fulfilled with the relevant equipping of stations with the modern equipment and instrumentation and with the provision of financial support of international organizations.

Unfortunately, because of the absence of the relevant instruments we could not start the monitoring of solar UV-B radiation in parallel with TOC measurement as well as the cycle of activities designed at the experimental estimation of the reduction of the crop capacity of agricultural crops in relation to the increase of UV-B radiation.

Since January 2001 the station for satellite information receiving from NOAA satellites is in operation at Uzgidromet. It was supplied by USAID agency as humanitarian aid.

The problem urgent necessity is to carry out the training courses for the young specialists of the republic with the aim of practicing new technical means for the measurement of ozone and flow of UV-B rays, measurement of traces of halloid-hydrocarbons, studying of the new mathematical models linking the atmospheric chemistry and climate as well as training related to the issues of the forecasting of the ozone layer behaviour.

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VIETNAM

Introduction

National Hydro – Meteorological Service of S.R. Vietnam (NHMS) have 3 ozone and UV-B observing stations. The observation is carried out since May 1992 in Hanoi station (21°00'N, 105°51'E). From 1994, Sapa station (22°21'N, 103°49'E) and Tan Son Hoa station (10°47'N, 106°42'E in Ho Chi Minh City) also start observing regularly. All the management for the ozone and UV-B observation in NHMS is operated by the Aero – Meteorological Observatory (AMO).

Observational Activities

The Total amount of atmospheric ozone (TO3) and UV-B are measured by M124 filter instrument, manufactured in Russia. The TO3 is measured 7 times per day with the sun height is in between 20° and 70°. The UV-B is measured 11 times per days from 7h to 17h LT (within period of 1st May to 31st October), and 9 times per day from 8h to 16h LT (within period of 1st November to 30th April).

From 2002 to 2005, AMO have sent all M124 for calibration in GGO (Petersburg, Russia) 2 times, in July 2002 and in September 2004. Since the new filters of M124 were not available, so after the calibration few months, our M124 instruments could not give the data with high quality. Even though, all the 3 stations have to absorb TO3 and UV-B, following the National Guide for observation. AMO have sent 03 more instruments M124 for calibration but only coming September AMO would receive the calibrated one.

Results from observation and analysis

According to the Global Distribution of Total Ozone, measured by satellite, Vietnam is located in the region with the total amount of ozone is changed from 200DU to 300DU (1), minimum in winter and maximum in summer.

From 2003 to 6/2005, as indicated on the Table and Figure 1 the total ozone measured at Tan Son Hoa were changed in between 200DU to 280DU, accept from March of 2005 up to now the TO3 were less than 200. The trend of TO3 was not clear. In 2003 we have seen the maximum value of TO3 was in September (273DU). It seems irregular.

At the same time the TO3 measured in Hanoi was out of limits. AMO has reported to WOUDC the situation of fault data and stopped to submit the TO3 data measured in Hanoi since June of 2003. Only from November 2004 the M124 in Hanoi has been replaced by the calibrated one and the data has been submitted to WOUDC again (table and figure 2)

The TO3 measured at Sapa was out of limits too. The annual trend of TO3 was also opposite compare with the map of Global Distribution of TO3, measured by satellite. Maximum value of TO3 was observed in November or December of the year. The TO3 has been changed without stable trend. It is fault data since the M124 has been defected and only replaced by the newly calibrated one in January 2005. From Jan. 2005 to June 2005, the TO3 changes from 257DU to 301DU, within the limits. The highest value is observed in April 2005.
Table and Figure 1: Annual trend of TO3 measured at Tan Son Hoa.

<table>
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[Graph showing annual trend of TO3]
Table and Figure 2: Annual trend of TO3 measured at Hanoi.

<table>
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Table and Figure 3: Annual trend of TO3 measured at Sapa.

<table>
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So, last two years 2003 and 2004 the TO3 data measured in Vietnam has not been qualified due to the fault M124 and we have no budget for calibrating the equipments in Russia every year.

Since the ozone data was not qualified, the UV-B would not qualified too. So the UV-B data would not be reported here.

Projects and collaboration

Since September 2004, in the framework of SOWER/Pacific project, NHMS has been carried out the ozonesounding by ECC ozonesonde once per month. All the equipments needed for observation supported by the project. The on - site training has been conducted by the Japanese experts.
Future Plan

Since the filters of M124 will not be produced NHMS plan to replace the new equipment for ozone and UV-B observation and to continue the international collaboration in this field.

Needs and recommendations

1. NHMS needs the financial support to replace the equipment for measuring the TO3 and UV-B to meet the requirement of the quality of data.

2. NHMS's personnel’s need the scientific and technical training and more international collaboration.

3. NHMS needs the financial support for exchange of visits amongst personnel from the monitoring stations of NHMS and other countries for improve our personnel's operational skill and knowledge.

4. NHMS hope to receive the support to carry out the ozonesounding in Hanoi at least once a week since we conduct the radiosounding twice a day by the DigiCORA-RS sonde, manufactured by Vaisala Co., Finland.

Finally, I would like to thank to WMO/UNEP give me opportunity to attend this meeting and give the national report on ozone and UV-B monitoring activities in S.R. Vietnam and NHMS would expect more international support in this field.

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<td>WMO Consultation on Brewer Ozone Spectrophotometer Operation Calibration and Data Reporting (Arosa, Switzerland, August 1990).</td>
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<td>Report of the International Workshop on Dobson Ozone Data Re-evaluation (Greenbelt, MD, September 1991 ) (TD No. 489).</td>
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<td>Handbook for Dobson Ozone Data Re-evaluation (TD No. 597).</td>
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<td>Second WMO Consultation on Ozone Measurements by Brewer Spectrophotometer (Charlottesville, Virginia, 1-3 June 1992).</td>
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<td>Report of WMO/NOAA Meetings on Ozone Data Re-evaluation and use of Dobsons and Brewers in the G030S (Tenerife, June 1994).</td>
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